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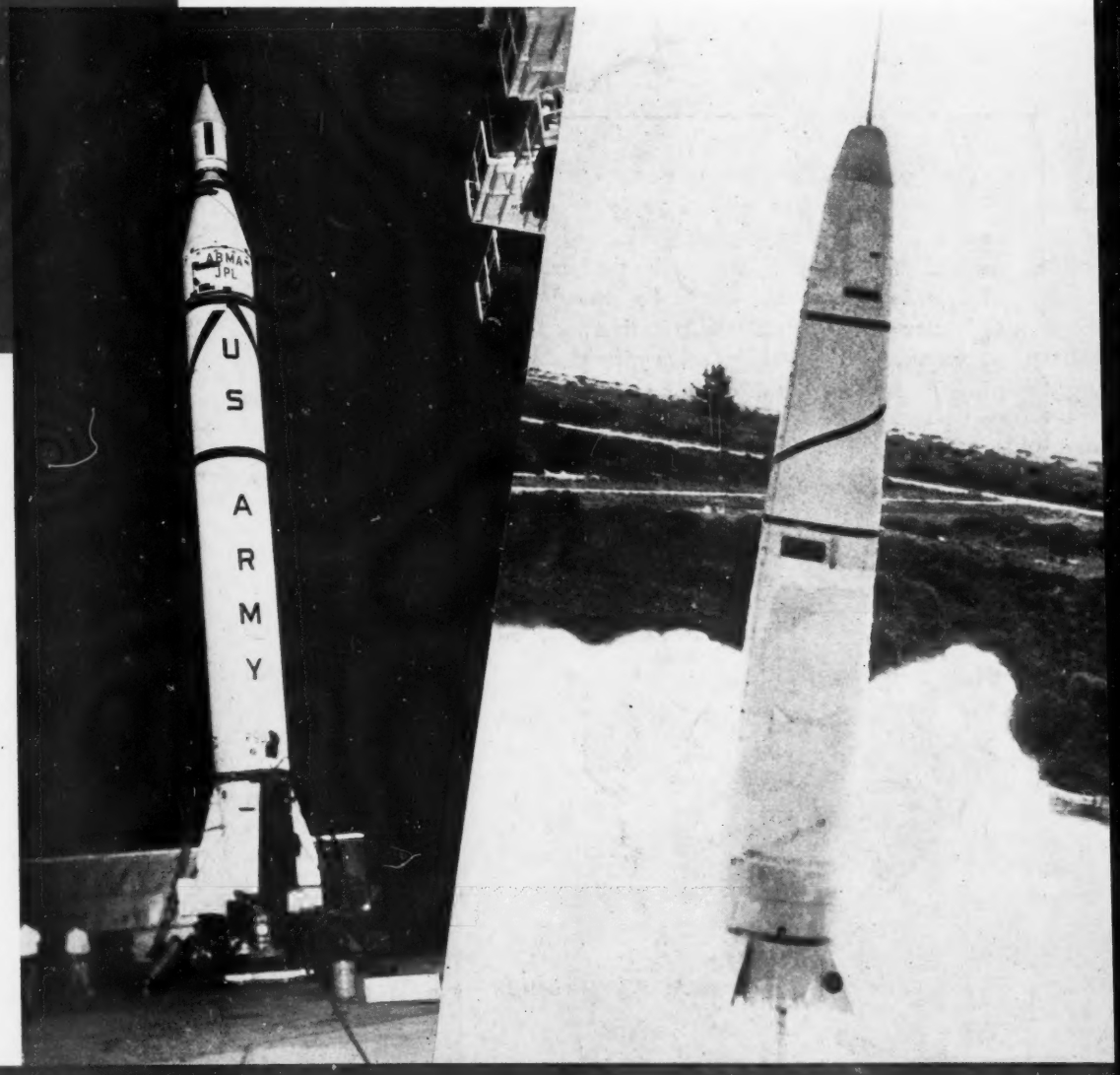

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. . . an editorial

January, 1958

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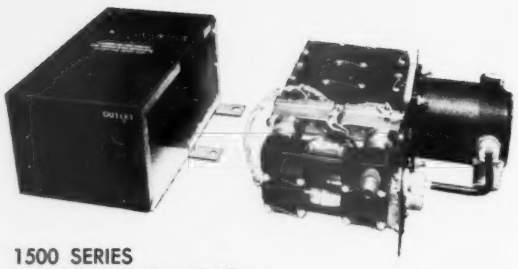

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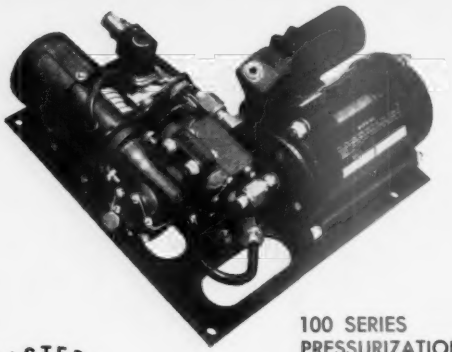

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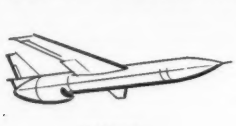

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Aeronautical Engineering Review: United States and possessions, 1 year, $5.00; single copies, $0.50. Foreign countries including Canada (American Currency Rates), 1 year, $6.00; single copies, $0.50.

Entered as second-class matter at the Post Office, Easton, Pa., April 29, 1942. Acceptance for mailing at a Special Rate of Postage as provided for in the Act of August 24, 1912.

Publication Office: 20th & Northampton Streets, Easton, Pa.

Editorial Office: 2 East 64th Street, New York 21, N.Y. Notices of change of address should be sent to the Institute at least 30 days prior to actual change of address.

Statements and opinions expressed in the Aeronautical Engineering Review are to be understood as individual expressions and not those of the Institute.

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Aeronautical Engineering Review

Vol. 17—No. 1 January, 1958

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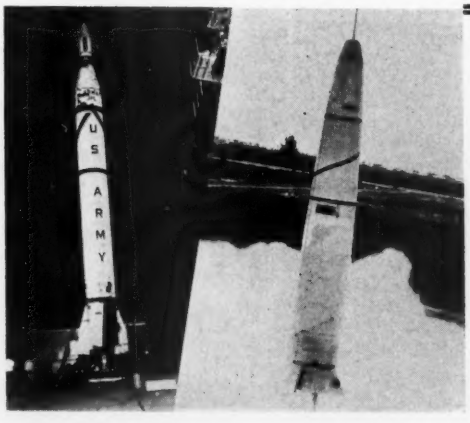


Cover—The Army Jupiter and Air Force Thor IRBM missiles will be sent to Great Britain by the middle of next year, according to Defense Secretary Neil McElroy. The Jupiter *(left)* is manufactured by Chrysler Corporation; the Thor is a product of Douglas Aircraft Company, Inc. The 1,500-mile-range missiles also will be sent to other NATO countries.

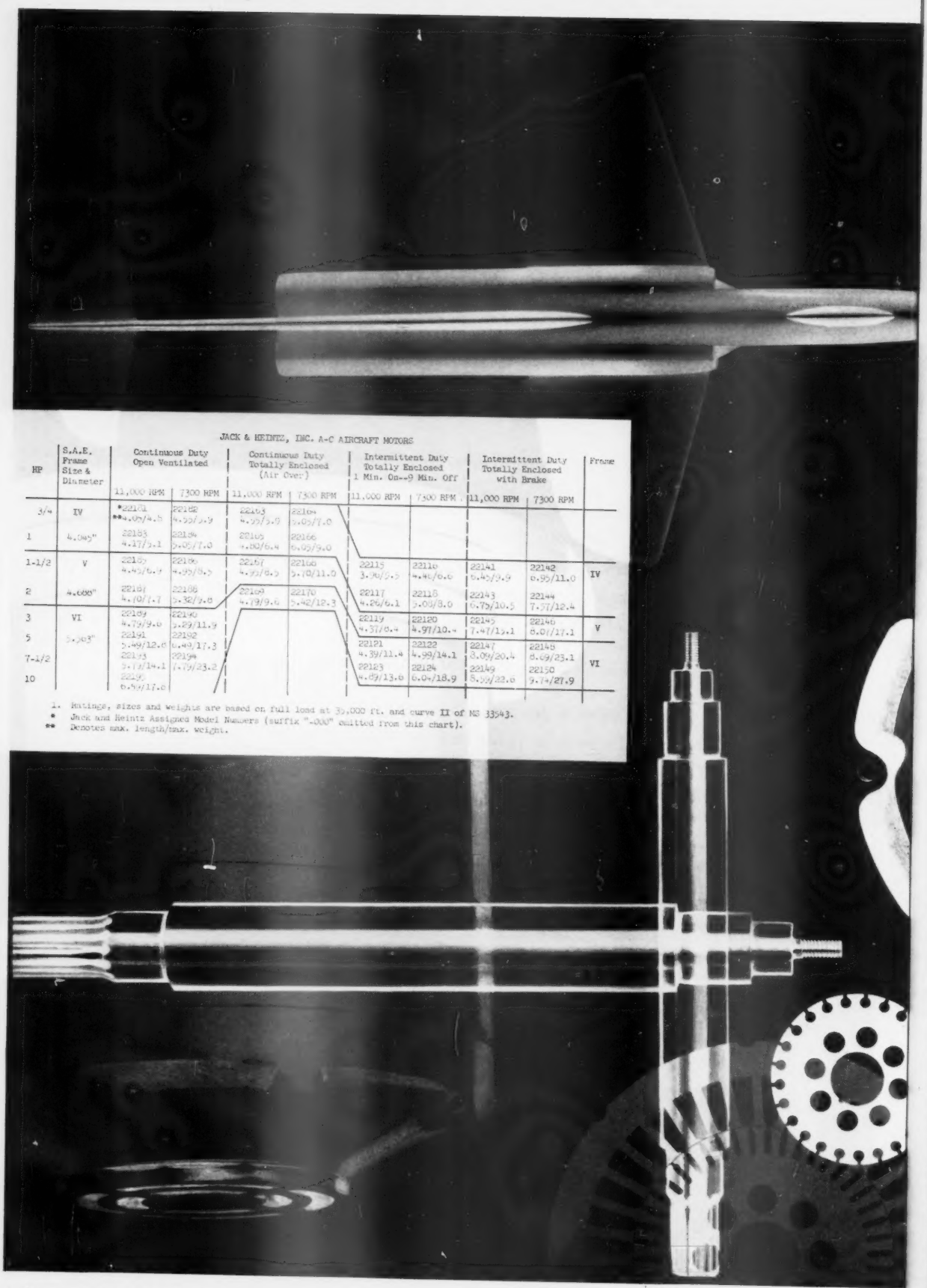
Published Monthly by the

Institute of the Aeronautical Sciences, Inc.

2 East 64th Street, New York 21, N.Y.

TEmpleton 8-3800

Western Office: 7660 Beverly Blvd., Los Angeles 36, Calif.



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IAS News Notes

January 1958

ANNUAL MEETING LUNCHEON SPEAKERS will be Hugh Dryden, NACA Director, January 27; Rear Admiral Robert E. Dixon, Chief, BuAer, January 29; and Sir George Edwards, Managing Director, Vickers-Armstrongs (Aircraft) Limited and President, RAeS, January 30.

NEW SERVICE FOR REVIEW READERS: Information on anything that appears in the REVIEW may be obtained by filling in the blank side of new postage-paid, self-addressed cards in the back of this issue.

IAS WORLD COVERAGE of air and space scientific and engineering work is pointed up by the LIST OF PERIODICALS on page 72 of this issue. This tabulation represents only the principal titles covered by the Aeronautical Reviews Section. More than 500 titles are acquired yearly by IAS National Headquarters Library. They come from scientific bodies, governments, universities, and commercial firms as follows: from North and South America, 332; Western Europe, 147; Eastern Europe (including Soviet Union), 37; Far East, 26; Near East, 2; and Africa, 1. Reprints of the list are available. The issues may be borrowed from the Library.

TWO IAS FELLOWS, Charles J. McCarthy, Board Chairman, Chance Vought Aircraft, and Vice Admiral James S. Russell, Deputy Commander-in-Chief, Atlantic Fleet, have been awarded the Collier Trophy for 1956 - for design and development of the F8U Crusader aircraft.

ADVANCED TRAINING in rocket, jet propulsion engineering and flight structures is offered through graduate fellowships at California Institute of Technology, Princeton and Columbia. Some 20 grants worth from $1,500 and $2,000 will be made by the Daniel and Florence Guggenheim Foundation, 120 Broadway, New York 5, N. Y. The Foundation will supply application forms which must be returned by March 1.

NATIONAL MEETINGS CALENDAR

Jan. 27-30	Twenty-Sixth Annual Meeting, Sheraton-Astor Hotel, New York.
Mar. 13-14	Flight Propulsion Meeting (Classified), Hotel Carter, Cleveland.
May 12-14	National Midwestern Meeting on Guided Missiles, Hotel Chase, St. Louis, Missouri.
July 8-11	National Summer Meeting, Los Angeles, California.
Sept. 8-13	First International Congress, International Council of the Aeronautical Sciences, Palace Hotel, Madrid, Spain.

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JOINT MEETINGS CALENDAR

Mar. 17-21 1958 Nuclear Congress, International Amphitheatre, Chicago. Coordinated by Engineers Joint Council.

June 2-4 National Telemetering Conference, Lord Baltimore Hotel, Baltimore, Maryland. Sponsored by IAS, ARS, ISA and AIEE.

June 19-21 1958 Heat Transfer and Fluid Mechanics Institute, University of California, Berkeley. Cosponsored by IAS.

SECTION MEETINGS CALENDAR

Jan. 7 San Diego Section: Specialist Meeting, IAS Building, 8 p.m. "Economics of Jet Transports" speaker to be announced.

Jan. 7 Los Angeles Section: Specialist Meeting, IAS Building, 7:30 p.m. "Modern Wind Tunnel Techniques" by Raymond L. Chuan.

Jan. 8 Philadelphia Section: Joint Dinner Meeting - IAS, ARS, SAE - Skyview Dining Room, Int. Airport, 7 p.m. "Manned Aircraft vs. Guided Missiles" by Rear Admiral John T. Hayward.

Jan. 9 Atlanta Section: Dinner Meeting, Atlanta NAS Officers Club, 7:30 p.m. "Navy Airborne Nuclear Power" by Capt. N.R.Richardson.

Jan. 9 San Francisco Section: Dinner Meeting, Ames Aeronautical Lab., 7 p.m. "Hypersonic Flight and the Re-Entry Problem" by H. Julian Allen.

Jan. 10 Los Angeles Section: Field Trip, Kaiser Steel, Fontana, Calif. Supper at 6:30 p.m., tour at 7.

Jan. 14 Washington Section: Dinner Meeting, Int. Room, Occidental Restaurant. (Social period at 6, dinner at 6:45) "The Changing Aircraft Industry" by General Orval T. Cook and A. J. Hayes.

Jan. 15 Texas Section: Specialist Meeting, Arlington State College, 8 p.m. "Boundary Layer Control" speaker to be announced.

Jan. 18 Rocky Mountain Section: Tour, Martin Company missile test sites, Denver, 12 noon. (Limited to Section members and one guest each)

Jan. 21 Los Angeles Section: Specialist Meeting, IAS Building, 7:30 p.m. "Theory and Experiment on Noise Generated by Jets" by A. Powell.

Jan. 23 Los Angeles Section: Dinner Meeting, IAS Building. (Social at 6, dinner at 7.) "Put the Man Back into the Missile" by Brig. Gen. Donald W. Flickinger and Scott Crossfield.

Jan. 28 Kansas City Section: Dinner Meeting, place to be announced. (Social at 5:30, dinner at 6:30.) "Engineering History of McDonnell Products" by Mike Weeks.

Feb. 6 Baltimore Section: Specialist Meeting, Bendix-Friez, 8 p.m. CLASSIFIED "ICBM" by Major General Bernard Schriever.

Mar. 13 Baltimore Section: Specialist Meeting, Martin Company, 8 p.m. CLASSIFIED "The Future of Missiles" by Simon Ramo.

* * * * * * *

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IAS News

A Record of People and Events of Interest to Institute Members

Edward C. Wells Elected President for 1958

Council Also Announces Election of Four New Vice-Presidents and Treasurer to Take Office After Annual Meeting

Edward C. Wells

EDWARD C. WELLS, 47, Vice-President—Engineering, Boeing Airplane Company, Seattle, Wash., has been elected President of the Institute of the Aeronautical Sciences for 1958, succeeding Mundy I. Peale, President, Republic Aviation Corporation.

Mr. Wells, a Fellow of the Institute, was a member of the IAS Council last year. He will be installed in office at the Honors Night Dinner held in connection with the Twenty-Sixth Annual Meeting, January 27–30 at the Sheraton-Astor Hotel, New York. The dinner will be on Tuesday, January 28.

The Council, following a meeting in Dallas, Tex., on November 7, also announced the election of four Vice-Presidents and the Treasurer for 1958.

New Vice-Presidents

The new Vice-Presidents are:

Neil Burgess of Cincinnati, Ohio, Manager, J-79 Project, Jet Engine Department, Aircraft Gas Turbine Division, General Electric Company. He is an Associate Fellow of the Institute.

General B. W. Chidlaw, USAF (Ret.), of Cleveland, Vice-President and Director, Thompson Products, Inc. General Chidlaw is a Fellow of the Institute.

L. Eugene Root, Vice-President and General Manager, Lockheed Aircraft Corporation, Missile Systems Division. He is an IAS Fellow.

H. Guyford Stever, Professor of Aeronautical Engineering and Associate Dean, School of Engineering, Massachusetts Institute of Technology, Cambridge, Mass. He was named a Fellow of the IAS last year.

Speas Named Treasurer

For 1958 Treasurer, the Council chose R. Dixon Speas, Aviation Consultant with his firm R. Dixon Speas Associates, New York. An IAS Associate Fellow, Mr. Speas also is a member of the AERONAUTICAL ENGINEERING REVIEW Editorial Advisory Committee in the Air Transport and Operations field.

The Council re-elected S. Paul Johnston as Director of the Institute. Mr. Johnston will begin his thirteenth year with the IAS in May. Also re-elected were Secretary Robert R. Dexter and Controller Joseph J. Maitan.

Wells B-17 Designer

Mr. Wells has been a Vice-President of the Institute. In 1942 he received the Institute's Lawrence Sperry Award "for outstanding contributions to the art of airplane design with special reference to four-engine aircraft."

He has had a direct and immediate part in the design development of the Boeing B-17 Flying Fortress, B-29 Superfortress, C-97 Stratofreighter, 377 Stratocruiser, B-47 Stratojet, B-52 Stratofortress, and the Model 707 Jet Stratotanker-Stratoliner.

A native of Boise, Idaho, Mr. Wells was made Chief, Preliminary Design Unit, at Boeing in 1936, and 2 years later was named Chief Project Engineer, in charge of Military Projects. In 1939 he became Assistant Chief Engineer and in March, 1943, was named Chief Engineer.

He became Vice-President—Chief Engineer in May, 1947, and has held his present title of Vice-President—Engineering since July, 1948. He was elected to the Boeing Board of Directors in 1951.

The new IAS President was born on August 26, 1910, and attended elementary school in Boise. He completed his high school education at Grant High School in Portland, Ore., and attended Williamette University for 2 years before entering Stanford University.

He was graduated from Stanford "with great distinction" in 1931, receiving a Bachelor of Arts degree in Engineering, with scholastic honors including election to Phi Beta Kappa and Tau Beta Pi. While attending Stanford he obtained a summer job at the Boeing plant, and upon graduation he joined the Boeing engineering staff on a permanent basis.

In 1946 Mr. Wells was granted an honorary Doctor's degree (LL.D.) by the University of Portland, and in 1953 he was granted an Honorary Doctor of Science degree by Williamette University. He was elected to this university's Board of Trustees in 1955.

Mr. Wells became a member of the American Society for Engineering Education in June, 1957, and in September accepted an appointment to the advisory board of the Washington State Institute of Technology at Pullman, Wash. His many honors include Seattle Junior Chamber of Commerce "Young Man of the Year" (1943) and the Fawcett Aviation Award for 1944, presented each year by the publishing firm to the person making the greatest scientific contribution to aviation.

Mr. and Mrs. Wells have two children, Laurie, a daughter, now a junior at Stanford, and Edward, a son, now a senior in high school.

Donald W. Douglas, Jr., Elected President of Douglas Aircraft

A 40-year old Associate Fellow of the Institute has been named President of one of the world's largest aircraft manufacturing firms. Donald W. Douglas, Jr., assumed the post vacated by his father Donald W. Douglas, Sr., an IAS Honorary Fellow and Benefactor and founder of Douglas Aircraft Company, Inc.

Mr. Douglas, Sr., remains Chairman of the Board and the chief executive officer of the company.

The election by the Board of Directors of the younger Mr. Douglas comes after nearly 20 years in the aircraft industry. He has served in many technical, experimental, sales, administrative, and executive capacities. He was formerly Vice-President in charge of Military Relations.

First World Aeronautical Congress Moves Toward Realization

A preliminary meeting to discuss plans for the First International Congress of the Aeronautical Sciences (Madrid, September 8–13, 1958) was held by the Executive and Program Committees, International Council of the Aeronautical Sciences, in London on September 4.

The majority of discussion was on a technical program for the Congress, and a list of twelve general subjects for possible presentation was drawn up. Included in these were supersonic wing, wing-body combinations; hypersonic flow, missile aerodynamics; heat transfer, problems of heat barrier; VTOL-STOL, stability; boundary-layer control; propulsion methods in astronautics; and human engineering (limits of human flight).

Representatives agreed that the topics should be broken down into a series of some 40 lectures. Consideration was given to a distribution of lecture subjects over a 1-week period.

The most highly qualified person for a specific subject will be sought by the Provisional Council Member in each country.

Major Gen. Boyd Retires From USAF Received 1955 Octave Chanute Award

Major Gen. Albert C. Boyd, an IAS Fellow and ARDC Deputy Commander for Weapon Systems, has retired from the Air Force after 30 years of service.

General Boyd was recently awarded the Distinguished Service Medal for outstanding contributions in the advancement of aircraft testing methods during his assignment with ARDC. The citation said his " . . . technical ability, leadership, and personal exploits have furthered the cause of aviation and demonstrated the unlimited potentialities of jet flight," and he contributed to " . . . the rapid introduction of new and improved weapon systems into the Air Force inventory."

He is one of two USAF officers who have flown the B-58 and has flown all

Donald W. Douglas, Jr.

Century Series fighters and the Caravelle, F-27, and 707 transports. Heading the list of honors General Boyd has received at home and abroad is the Institute's Octave Chanute Award for 1955.

In the Air Force he is referred to as "the test pilot's test pilot," and from his composite flying experience it could be said that he has flown faster, farther, higher, and longer than any other USAF officer.

Doolittle, Furnas Honored by University of Michigan

James H. Doolittle (HF), and Clifford C. Furnas (F), have been awarded Honorary Doctor of Engineering degrees by the University of Michigan at the dedication of the school's new Aeronautical and Automotive Engineering Laboratories.

General Doolittle, Vice-President of Shell Oil Company and Past President of the IAS, was cited as "aviator, pioneer in aeronautics, military strategist." Dr. Furnas, Chancellor of the University of Buffalo, delivered the main address, "Transportation and Its Future Technology," at the dedication.

NEWS OF MEMBERS

▶ **Winfield H. Arata, Jr.** (AF), Chief Operations Engineer, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation, presented a technical paper, "Prop-Jet and Turbojet Business Aircraft," to the Weybridge Branch of The Royal Aeronautical Society at Weybridge, Surrey, England, on October 2. Mr. Arata had given this paper previously at the IAS National Summer Meeting in Los Angeles, Calif.

Ernest G. Stout (F), formerly Assistant Division Manager, Project Development, The Ralph M. Parsons Co., Los Angeles, has been named Assistant Manager, Washington Office. Mr. Stout, Parsons IAS Corporate Member Representative, also has been elected to the Board of Directors, Air Craft Marine Engineering Co.

▶ **Herbert Arnow** (M), Project Engineer at the Bureau of Aeronautics, Representative, USN Department, Bethpage, N.Y., has been granted an award by the Incentive Awards Committee for evolving improved engineering methods and procedures which resulted in savings to the Government said to be more than $500,000 within the past year. In addition to the award, Mr. Arnow was voted an Outstanding (O) rating for his work.

▶ **Wolfgang B. Klemperer** (F), Chief, Missiles Research Section, Douglas Aircraft Company, has received the honorary degree of Doctor of Technical Sciences from the Institute of Technology in Vienna, Austria. The award was conferred for his "pioneering and internationally recognized research work in the field of aeronautics."

▶ **Seymour Lieblein** (M), Aeronautical Research Scientist, Lewis Flight Propulsion Laboratory, has been awarded the National Advisory Committee for Aeronautics' Exceptional Service Medal, for "significant scientific results in the field of axial-flow compressors," during the years 1952–1957. The citation also states that Mr. Lieblein's work has resulted in reduced weight and cost of compressors.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

Serge A. Alexeeff (M) last May joined North American Aviation, Inc., as Senior

Structural Engineer. In the November REVIEW it was incorrectly reported that he had assumed this position with the National Aeronautic Association. Prior to joining North American, Mr. Alexeeff was Weight Engineer, Vertol Aircraft Corporation.

Roland Boucher (A), formerly a Stress Engineer, Avro Aircraft Ltd., has joined General Dynamics Corporation, Canadair Limited (Subsidiary).

Capt. Roy E. Hale, Jr., USAF (M), has been awarded a Master's degree in Aeronautical Engineering from the Air Force Institute of Technology and has been assigned to ARDC Headquarters Aeronautics Division as Assistant Chief, Aerodynamics Branch.

Albert P. Martine (M) has joined the Navy Computation and Exterior Ballistics Laboratory at Dahlgren, Va., Proving Grounds as an Aeronautical Research Engineer in the Missile Evaluation and Development Branch, Exterior Ballistics Division. He formerly was an Aeroelasticity Investigations Engineer in the Flight Propulsion Laboratory Department, Aircraft Gas Turbine Division, General Electric Company.

John Dill McKenney (A), formerly Director, Weapons System Development Program at California Institute of Technology Jet Propulsion Laboratory, has been appointed Principal Engineer, Aircraft and Automatic Controls Division, Clary Dynamics Corporation.

Irving Michelson (A), formerly President of Odin Associates, Pasadena, Calif., has been named Professor and Head of the Department of Aeronautical Engineering, The Pennsylvania State University.

Maurice Nelles (M), formerly Director of Diversification and Research Development, Technicolor Corporation, has been elected Vice-President for Engineering, Crane Co., manufacturer of valves, fittings, plumbing and heating equipment.

Jerome Persh (M), formerly of the Aerodynamics Department, U.S. Naval Ordnance Laboratory, White Oak, Md., has joined the Special Projects Office, Navy Bureau of Ordnance, Washington, D.C.

David Proudlove (A), former British Civil Air Attaché in Washington, has been named President of the Bristol Aeroplane Company (U.S.A.) Inc., at 400 Park Avenue, New York.

John Ruptash (M) has joined the faculty of Rensselaer Polytechnic Institute as Visiting Associate Professor, Department of Aeronautical Engineering. He formerly was Professor of Aerodynamics at the University of Wichita.

Herbert G. Somerson (M), formerly Chief Analytical Engineer, Piasecki Aircraft Corporation, has been appointed Chief Technical Engineer for the company.

Maurice A. Walter (M) has been appointed Assistant Section Chief, Advance Engineering, Servomechanisms, Inc., Hawthorne, Calif. He formerly was a Senior Project Engineer for the firm.

H. A. Wente (A) and H. R. Vaughn (A) ***(third and fourth from right, respectively)*** **provided the aerodynamic design of this Sandia Corp. high-altitude research rocket said to reach an 80,000-ft. altitude. The 12-ft. long single-stage missile performed a series of upper atmosphere tests at the AEC's Tonopah Ballistics Range, Nevada, in connection with nuclear weapons development work.**

Necrology

Curtis P. Liljengren

The Institute has received word of the death of Curtis P. Liljengren (M), 38, on October 11. Mr. Liljengren was President, Liljengren Engineering Co., Miami, Fla.

He was a 1942 graduate of the University of Minnesota where he received Bachelor degrees in Aeronautical Engineering and Business Administration and held an Assistantship on Aircraft Engines and Thermodynamics.

From 1942 to 1945, Mr. Liljengren was with Pan American Airways in successive positions as Cost and Supplies Engineer, Trainer Plane Engineer, Radio Modification Project Engineer, and DC-3A Project Engineer, Latin American Division.

Capt. Gerald E. King, USAF

News of the death of Capt. Gerald E. King (A), 29, has been received by the Institute. Captain King was an Air Force Experimental Test Pilot working on the F-100F at Eglin AFB, Fla.

Captain King was the winner of the University of Colorado IAS Student Branch Scholastic Award in 1956. In June of that year, he was graduated with special honors, receiving a B.S. degree in Aeronautical Engineering. Later, he was graduated from the USAF Test Pilot School at Edwards, Calif.

A native of Anton, Colo., he also held a commercial pilot's license.

CORPORATE MEMBER NEWS

• **Aerojet-General Corporation,** Turbo-Machinery Division, has announced a brushless alternator with no moving parts except a rotor made of solid metal. Use of inert insulation is said to make the alternator suitable for work at temperatures beyond 800°F.

• **Aeroquip Corporation** has announced the appointment of Mathias A. Gatzweiler as Production Control Manager, Jackson Division.

• **Airborne Accessories Corporation** has appointed Robert E. Svozil Plant Manager. He formerly was Manufacturing Manager, Technical Production Division, Allen B. Du Mont Laboratories, Inc.

• **Allis-Chalmers Manufacturing Company** has released a new bulletin, *Type H Motor Control* (14B8507), available on request, said to cover latest design features of the firm's Type H, front access, high-voltage starters.

• **Allison Division, General Motors Corporation,** reports that a 1,000-hour flight program for the Electra-bound prop-jet engine has been launched as the final phase of endurance tests.

• **American Airlines, Inc.,** plans to convert its operations to turbine-powered aircraft by 1961 through a program dependent upon the company's earning $25 million annually. Said to be the first complete conversion-to-turbine program by an American airline, it calls for a fleet of 105 turbojet and turboprop aircraft. The firm's Board of Directors has elected Charles H. Startup Assistant Vice-President, Customer Service.

• **Amphenol Electronics Corporation** is manufacturing a full line of miniature electrical connectors named "minniE," said to be the first to conform fully to "E" performance requirements of MIL-C-5015C. Two new publications available from the firm are *The New World of Electronics*, covering factors affecting electronic development, and a new edition of Manual C-4 *OK Methods Manual* devoted to An, miniature AN, power, audio microphone, and RF connectors.

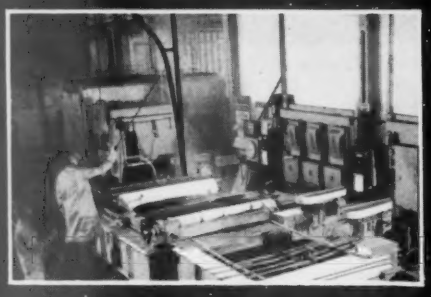
• **Avien, Inc.,** has announced the appointment of Berkeley S. Boyd as regional representative in Dayton, Ohio.

• **Bell Aircraft Corporation** reports its GAM-63 Rascal missile has scored four direct hits in firings from a B-47 bomber during tests at USAF Missile Development Center, N.M.

• **Bendix Aviation Corporation** reports that its Navy Talos missile, demonstrated publicly recently, features a "traffic

(*Continued on page 58*)

building the structure for modern flight



High-strength steel weldments

that develop strength of more than 200,000 pounds per square inch have been developed through an intensive, four-year research program at Rohr. Present day advancements in the performance and speed of aircraft make this process vital for special components with very high load factors such as fuselage bulkheads, control brackets, wing attach fittings and engine mounts. Their manufacture demands a high level of technology and specialized manufacturing equipment.

These high-strength steel weldments, now in volume production, are but one of the current structures programs at Rohr.

ROHR
AIRCRAFT CORPORATION

Main Plant and Headquarters: Chula Vista, California; Plant: Riverside, California; Assembly Plants: Winder, Georgia; Auburn, Washington

DATELINE World

PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

Flaking of Steel Probed by Eight Soviet Authors

◆ Soviet literature reveals that flaking of steels is a lively subject in the U.S.S.R., as it is in the U.S. where it has occupied a place of high interest, especially in aircraft quality and armament steels.

A total of eight authors have reported their research on the mechanism of forming flakes, and, strangely, none mentions vacuum-melting or vacuum treatment of steels to eliminate hydrogen, which is responsible for this phenomenon. However, the editors of *Stal Magazine*, which published these articles, have footnoted vacuum treatment in the ladle. While all these Soviet authors agree that flaking must be eliminated, each has a different hypothesis or theory for accomplishing it.

One paper by P. V. Skyuyev, L. I. Kvater, and V. Y. Shapiro, entitled "Effect of Hydrogen on the Mechanical Properties of Steel," is excellent and reflects favorably with the state-of-the-art comparable to that in the U.S., U.K., France, and West Germany.

Skyuyev, Kvater, and Shapiro investigated the effect of hydrogen on transverse reduction of area and elongation and on impact. They also studied the effect of various factors on hydrogen embrittlement: holding time at room temperature, strength level, structure, composition, and temperatures below room temperature. Most of the work was done on 34KhM, 34KhN3M, electrolytically charged with hydrogen. Some tests were made on steels 35, 35N3, 35Kh3, and 35Kh3M. Results were reported as follows:

(1) Increasing hydrogen content decreased transverse ductility but had less effect on impact and even less on ductility and toughness at low temperatures. All these results can be explained on the basis of the time needed for hydrogen to diffuse to slip planes or defects.

(2) Holding at room temperature caused an appreciable improvement in the properties damaged by hydrogen.

(3) Increasing strength level accentuated the embrittling effect of hydrogen. Structure was also a factor, and hydrogen had a more deleterious effect on the properties of acicular troostite than on sorbite and pearlite (Bainite).

(4) Carbon steel was less affected by hydrogen than alloy steel. Nickel additions caused little change, but 3 per cent chromium markedly increased the susceptibility to hydrogen embrittlement. A small addition of molybdenum to the chromium steel counteracted this effect of chromium. Further work is needed to explain this influence of molybdenum.

(5) In the present state of metallurgy, it is impossible to produce large sections of steel that are hydrogen free or have hydrogen contents below 1 to 2 cu.cm. per 100 gm., which would not affect the ductility. Therefore, it can be assumed that all heavy sections (at least at the start of processing) will contain excess hydrogen and therefore will have lower than normal ductility.

(6) The increasing requirements placed on machine parts make it essential to develop improved methods of melting, pouring, and heat treatment for heavy forgings.

U.S.S.R. Foundry Work With Isotopes Reported

◆ A 1956 paper by B. B. Gulyayev and L. G. Demina entitled "Control of Castings With the Aid of Radioactive Isotopes" reveals that the Soviets have done considerable work with isotopes in foundry work and that their efforts parallel those of the U.S. in this field.

The authors present a general review covering available isotopes, method of use, safety precautions, and sensitivity to various types of defect. Recently, inspection with radioactive isotopes has been adopted by more and more leading foundries since it gives a reliable control of the soundness of castings and may be effectively applied to develop foundry techniques.

Nothing new is presented in this paper, which is merely an attempt to popularize radioactive isotopes in the foundry. Past Soviet contributions on the subject include a 1953 paper by P. S. Koltunov, which mentioned only radium as a source of gamma rays, and a 1954 article by M. B. Neyman dealing in very general terms with practical applications of radioactive isotopes. The 1955 session of the Academy of Sciences gave a fairly complete view of the entire field, and a Neyman paper in 1955 was an attempt to tell the practical man about this development. The Gulyayev-Demina paper is a similar effort in the propaganda vein on "peaceful uses of the atom."

The available isotopes used in this field are said to be Co 60, Zn 65, Se 75, Ag 105, Cs 135, Ce 141, Ta 182, W 185, and Ir 192. The most popular, however seem to be the cobalt, tantalum, iridium, and selenium isotopes since these are the only ones for which specific irradiation charts are given. In the U.S. the cobalt and cesium isotopes would probably be most widely used in this field.

Hardenability Tests Taken Up in Soviet Paper

◆ A 1965 article by A. A. Gol'denberg entitled "On the Use of Different Modifications of End-Quench Hardenability Tests" reveals that the Soviet metallurgists, like their Western counterparts, have recognized some of the shortcomings of end-quenched specimens (Jominy-bar). Despite this, they have used the end-quench hardenability test for many years and have a standard specification (GOST 5657-51) covering it.

The author deals with the fields of application of the standard end-quench hardenability specimen and of a modified specimen with a "block" on the free end to retard cooling. He concludes that:

(1) For very low hardenability steels (low carbon steels with manganese on the low side) having a critical cooling rate over 200°C./sec., the end-quench test is unsatisfactory.

(2) For low- and medium-hardenability steels having a critical cooling rate from 14 to 150°C./sec., the standard end-quench specimen is satisfactory.

(3) For medium-alloy high-hardenability steels having a critical cooling rate from 9 to 14°C./sec., the modified "block" specimen should be used.

(4) For martensitic steels with critical cooling rates under 9°C./sec., other special hardenability specimens described in the literature should be used.

It has long been realized in the U.S. that the standard end-quench hardenability specimen is not suitable for steels with extremely low or extremely high hardenability. Special modifications for use where the standard specimen is not

(*Continued on page 125*)

EDITORIAL

TOWARD A HIGHER EDUCATION

During the IAS Weapons System Management Meeting in Dallas (November 7–8), a great deal of discussion developed outside the scheduled technical sessions concerning the dangerous level to which scientific and engineering education has fallen in the United States. President Eisenhower had not yet made his Oklahoma speech, but Sputniks I and II were orbiting merrily. By that time it was obvious to everyone that we were not witnessing any "freak" scientific accident. We found ourselves facing up to the unpleasant realization that the Russian "moons" are end products of sound basic research programs and of engineering "know-how" of a very high order—of a quality at least equal to our own. More disturbing still, we realized that this state of affairs did not happen overnight. It implied the existence of a long-range educational program that had begun to pay off.

As we pointed out editorially last month, Russia's space program is backed up by intensive educational preparation in basic science and in applied technology that reaches far down into elementary school levels. Russian school children begin their mathematic and scientific education at a very early age. By the time they finish secondary school grades, they have progressed well into advanced algebra, geometry, and trigonometry and have had several years in each of the basic sciences—physics, chemistry, and biology. In contrast, former President Hoover said in a recent speech in New York, ". . . the harsh fact is that [U.S.] high schools are not preparing youngsters for the entrance requirements that must be maintained by our institutions training scientists and engineers." He stated that a survey of our school records showed that fewer than 12 per cent of high school students study algebra and geometry, less than 9 per cent take elementary chemistry, and under 5 per cent take physics.

Apparently Russia's educators consider as perfectly normal a weekly work-load throughout the early years of schooling that would bring screams of protest from any American P.T.A. The teaching of scientific subjects intensifies as the more highly qualified students progress into the universities and more advanced technical schools. Also, reported in a recent government study of Soviet educational methods, both students and teachers of scientific subjects are held in high esteem. More importantly, the latter are adequately compensated for their work both in salaries and in prestige.

In the face of this staggering threat to our national complacency, the boys in the smoke-filled back rooms at Dallas put in many hours discussing ways and means to bolster up our scientific and educational programs in general and, specifically, what more the Institute of the Aeronautical Sciences can do to help the situation.

In a burst of initial enthusiasm it was suggested that the IAS, as a leading scientific society, should draft a resolution addressed to the President of the United States calling his attention to the perilous state of scientific education and demanding that something be done about it. Some quite impressive language (with many a "whereas" and "now therefore") was produced at this point. On second thought, however, it was agreed that the subject scarcely came under the heading of "news" to the White House. The President had already announced his intention to discuss our deficiencies in scientific education in his Oklahoma speech. It was a fair guess also that the "In" basket of the White House Secretary-for-Handling-Resolutions was already overflowing with similar high-sounding documents from foundations, associations, and societies all over the country. It seemed therefore that the "do-something-about-it" angle was far and away the most important and that we should take a good look at what the IAS has already accomplished in the past and what we can do in the future to come up with some positive suggestions for further action.

Most IAS members are aware that during its entire history the Institute has taken very great interest in scientific educational programs. From its inception, requirements of students for professional guidance were recognized. The establishing and servicing of Student Branches in the more important educational institutions offering courses in Aeronautical Engineering were among our earliest activities. In recent years it has become clear that our obligation to encourage young people to enter scientific and engineering work necessarily extends down into the preparatory schools.

During the past few years the work of our 70-odd Student Branches and the programs of our eight annual National Regional Student Conferences have been supported by our Minta Martin Aeronautical Student Fund. In addition, many of our Sections have Student Advisory Committees and have been participating actively in local radio and television campaigns beamed toward potential engineering students at the high school level. We have also distributed about 100,000 copies (three editions) of our *Vocational Guidance Manual* to high school guidance counselors and some 125,000 copies of *Your Career as an Engineer in Aviation* directly to high school students.

One of the most important contributions that has been made under IAS auspices, however, has just come to fruition. Not quite 2 years ago a group of people in our Los Angeles Section, alarmed by the growing shortage of qualified personnel, organized themselves into the prototype Engineering Career Development Committee. In the initial discussions it was disclosed that most Corporate Members of the IAS had scholarship or educational aid programs in operation or in prospect. It was recognized that such efforts were important to help alleviate the shortage of engineers. It was agreed that the ECDC would undertake the job of correlating and publishing useful material on such subjects for the benefit of all. The Committee went to work on the basic outline and content for an IAS education manual.

In January, 1957, the initial efforts of the Western Region ECDC were strongly approved by the IAS Council, and the extension of the Committee's work to Eastern and Midwestern regions was authorized. As a result of the combined efforts, a limited number of the first *Corporate Aid to Education Manual* of the Institute of the Aeronautical Sciences is currently being distributed to all of our Corporate Members and to selected educational and industrial associations. The *Manual* is in loose-leaf form; it is our intention to expand it as additional material becomes available. It contains tabulated information based on extensive research in such areas as "Financial Aid to Colleges," "Nonfinancial Aid to Colleges," "Secondary Schools," "Youth Motivation," etc. It is backed up by extensive bibliographies and reference lists of organizations and agencies interested in the subject. In a pocket in the back cover is a collection of pamphlets and booklets from such organizations as Council for Financial Aid to Education, National Aviation Education Council, Aircraft Industries Association, etc.

Every member of the IAS can be proud of this effort. It is a worthwhile contribution toward the solution of a difficult problem. The members of the Western Region ECDC are to be congratulated for their foresight, their energy, and their accomplishment. They have set a high standard for the continuing work of the three National ECD Committees. We will all continue to support this project.

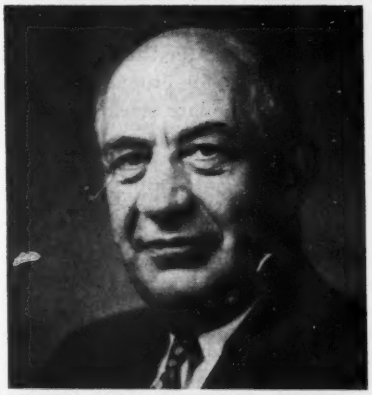
But the publication of the *Manual* is not an end point. It is only one useful tool for attacking the larger problem. ECDC members who participated in the informal discussions in Dallas felt that we now need some high-level guidance to ensure that all the educational activities of the IAS be coordinated and headed in the proper direction.

The IAS has within its own membership many of the most experienced and able educators in science and technology in the United States. It was suggested that a small group of such people be asked to serve as an Advisory Committee to which the entire IAS and its ECDC and other committees could look for overall policy guidance. President Peale, who participated in many of the Dallas talks, immediately appointed a group of five senior members of the IAS who are recognized in the educational field to act as the IAS Educational Advisory Committee. (Pictures appear at right.)

It is planned that the Committee will meet during one of the days of the Twenty-Sixth Annual Meeting in January. It will be available for discussion purposes with members of the ECDC and others in the IAS who are concerned with educational programs anywhere. Theirs will be a continuing function. We hope that out of this activity will come recommendations and action for long-range support by the IAS for the national program for the improvement of scientific education as outlined by President Eisenhower.

The IAS has already done much in this field—it can, and will, do more.

S.P.J.



IAS Educational Advisory Committee

Preston R. Bassett • Charles H. Colvin • Clifford C. Furnas
Clark B. Millikan • Theodore P. Wright

To provide policy, guidance, and advice for the Institute's various educational programs, President Peale has appointed this group of senior IAS members. Each has had long experience in the educational field. Four of them are Past Presidents.

Robert B. Ormsby, Jr.
Lockheed Aircraft Corporation

AIRBORNE NUCLEAR PROPULSION SYSTEM

Design Considerations

The gross weight variation of ANP aircraft is examined to point out the basic underlying reasons why ANP aircraft are inherently large and to determine what can be done to make them smaller. Increasing the reactor power density promises some improvement in that increasing the reactor power density by a factor of 2 reduces aircraft size by one third. Improved materials which will withstand high temperatures and massive doses of nuclear radiation will permit increased reactor power density and reduced aircraft size.

THE APPLICATION of nuclear power to various modes of transportation is receiving considerable attention. The basic reason is obvious: nuclear power can greatly increase the range or endurance of any vehicle requiring heat for propulsion. The major difficulty is providing adequate shielding to reduce the radiations produced in the nuclear fission process to levels that are reasonably safe. Since reactor shielding is inherently heavy and bulky and since aircraft performance is extremely sensitive to these factors, the use of nuclear power for aircraft propulsion presents probably the most difficult application of nuclear power to mobile systems. Many articles have appeared in various publications describing nuclear-powered aircraft. These articles generally state that ANP aircraft will be large. This statement taken by itself is not very enlightening. It is the purpose of this article to examine this size variation a little more closely to point out the basic underlying reasons why ANP aircraft are inherently large and to determine what can be done to improve the situation.

AIRPLANE DESIGN

The general aircraft type selected for examination in this paper is a conventional subsonic design, termed, in these days of supersonic speeds and high altitude, a low performance design. Four aircraft gross weights are selected to demonstrate the effect of aircraft size. These four gross weights are 100,000 lbs., 300,000 lbs., 600,000 lbs., and 1,000,000 lbs. The cruise speed is selected to be 200 knots and the cruise altitude 20,000 ft. For this cruise speed, a gas turbine driving a propeller is the ideal power plant for nuclear power for two reasons. First, the Brayton cycle used in current gas-turbine engines lends itself to the steady heat of nuclear fission. Second, for the flight speeds postulated for this paper, a propeller provides more efficient utilization of the power produced in the reactor.

To determine the power requirements for the aircraft designs, the cruise condition is selected. In a detailed aircraft design study, other flight conditions might be more critical. For instance, take-off power and climb with one engine inoperative have in many cases more stringent power requirements than the cruise condition. But for the purpose of this paper, any one of these conditions can be selected and the choice of the cruise condition is made.

An aircraft lift/drag ratio, or L/D, of 20 is quite reasonable. For this L/D the drag of these designs is 5,000 lbs., 15,000 lbs., 30,000 lbs., and 50,000 lbs., respectively. The thrust horsepower required may be obtained from the relationship $THP = (Drag \times velocity, knots)/325$. For the 100,000-lb. airplane, this is 3,080 hp. The brake horsepower is computed by $BHP = THP/$propeller efficiency. Modern propellers have efficiencies from 85 to 90 per cent. Using 85 per cent, the brake horsepower required for cruise is 3,630. This power must be converted into a reactor power requirement in order to determine the shield size. Assuming that a nuclear turboprop engine can be efficient as a chemical counterpart, the fuel consumption of the chemical engine can be converted into megawatts of heat using conventional efficiencies. Turboprop engines are being designed to achieve a specific fuel consumption of 0.40 lb. of fuel/BHP-hour. Using a heating value of 18,000 B.t.u./lb. for hydrocarbon fuel, this becomes 2,100 watts/hp. It can be seen that this represents an overall efficiency for these engines of about 35 per cent. Since the airplane power requirement is 3,630 hp., it is readily seen that the heat that must be supplied to the engines is 2,100 watts/hp. $3{,}630 = 7.62 \times 10^6$ watts. This value must be increased to allow for various losses in the reactor and shield assembly, and a reactor efficiency of 75 per cent is

Mr. Ormsby is Project Leader, Airborne Nuclear Propulsion Systems Group, Military Operations Research Engineering Division.

assumed. Thus, to supply 7.62 megawatts to the engines, a reactor power of $7.62/0.75 = 10.16$ megawatts is required.

Reactor Shield Requirements

Computing a reactor shield is a very involved and tedious process if maximum accuracy is required. For the purposes of this exercise, the process may be simplified considerably and the resulting discrepancies are lost within the accuracy of the assumptions which must be made in compliance with security restrictions. Further, to simplify the calculations, only unit shielding will be considered—that is, all the shielding material is placed around the reactor.

The reactor shield must attenuate the radiation to human tolerance levels if human beings are to be permitted to operate the aircraft. The allowable dose rate is assumed to be equal to that established by the AEC for civilian laboratory workers, or about 0.3 rem/week. If a flight crew is to fly about 100 hours per month, a reasonable figure, the crew dose rate requirement is about 0.01 rem/hour.

The radiation to be shielded consists of neutrons and gammas of various energy levels. The alpha particles and beta rays are not nearly as penetrating and are absorbed in the reactor core or in the core supporting structure. For the purposes of approximating a shield design, only the more penetrating energy levels need be considered since the shielding which attenuates the high energy particles to acceptable levels suffices virtually to eliminate the lower energy particles. The amount of attenuation required can be computed knowing the reactor power, the required dose rate, and that fission produces 7×10^{10} fast neutrons/sec./watt and 3×10^{11} fast gammas/sec./watt.[1] In addition, the geometry of the reactor and crew area must be considered. If the rear face of the crew compartment is 10×10 ft., or 100 ft.^{2}, and the reactor is 50 ft. away, the radiation coming through a solid angle of the reactor core of 0.0314 steradians strikes the crew area. Since there is a total of 4π steradians in a sphere, the amount of radiation striking the rear face of the crew compartment is $0.0314/4\pi$, or 0.0025 of the total radiation. This should be increased to allow for additional radiation that arrives at the crew compartment because of air scattering, build-up in the shield, and other factors. A factor of approximately 10 is arbitrarily assumed, and the 0.0025 factor is increased to 0.03.

The total number of neutrons produced in a 10-megawatt reactor is 7×10^{16} neutrons/sec. and 3×10^{17} gammas/sec. Applying the modified geometric factor of 0.03 and the fact that one third of the radiation leaks from the core, the number of neutrons coming through the back of the crew compartment is 7×10^{14}/sec. and the number of gammas is 3×10^{15}/sec. Considering the area of the crew compartment, these values can be converted into flux. The neutron flux is 7.53×10^{9} neutrons/cm.^{2}/sec. and the gamma flux is 3.23×10^{10} gammas/cm.^{2}/sec. As stated in reference 1, 2.8×10 fast neutrons/cm.^{2} or 2×10^{9} high energy gammas/cm.^{2} produce a dose of one rem. Assuming that the dose of 0.01 rem/hour established earlier can be divided evenly between neutrons and gammas, the neutrons must be attenuated by a factor of 2×10^{8} and the gammas by 1.17×10^{7}.

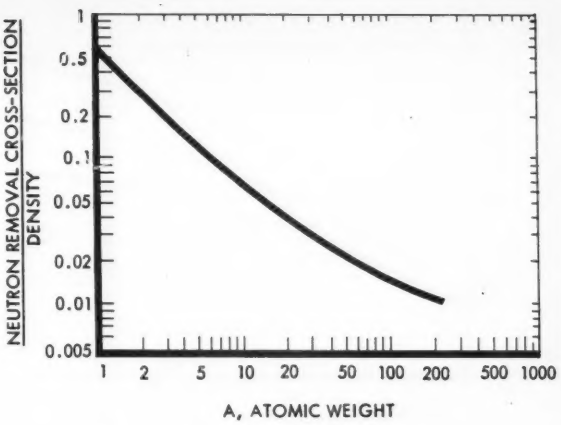


Fig. 1. Fast neutron shielding efficiency.

Reactor Shield Design

With the required attenuation factors determined as above, the reactor shield can be designed. First of all, the materials to be used must be selected. There frequently appears in the "popular" literature a discussion of shield materials which leads the uninitiated to believe that, with enough research effort, a "magic" shield material weighing nothing and shielding all can be developed. This is unlikely as the following discussion will show.

Considering first the neutron shielding material, Fig. 1 shows the microscopic removal cross section divided by the density. It is clear that the highest neutron attenuation per pound of material is attained with hydrogen. Since pure hydrogen is difficult to handle, the best neutron shield is, then, an easily handled compound of hydrogen, having a high hydrogen content. While water does not have maximum hydrogen content per unit weight, it is readily available and is easily handled. Therefore, the neutron shielding material to be considered is water.

Gamma rays are attenuated by three processes: photoelectric effect, Compton effect, or pair production. Table I shows how the gamma attenuation varies as a function of atomic number, Z, for these three processes.

It is clear that the higher the atomic number, the higher the gamma attenuation. Since material density is very roughly proportional to the atomic number

Table I

Energy Range	Gamma attenuation cross section varies as
$\leq$0.5 Mev	Z^5
0.5 to 5.0 Mev	Z
$\geq$5.0 Mev	Z^2

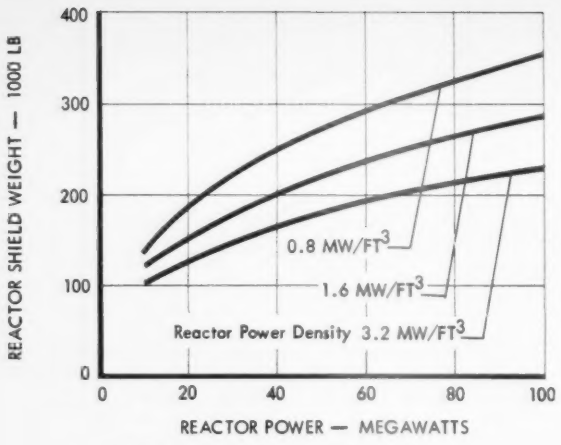


FIG. 2. Reactor shield weight.

Z, it is apparent that the denser the material, the lighter the gamma shielding, since for two of the three energy ranges shown in Table I, the attenuation is a function of some power of Z. Lead is the heaviest element which is stable and is, therefore, selected for the gamma shielding material on the grounds that it will provide maximum attenuation for a given weight.

Knowing the shield materials and the required attenuation factor, the shield thickness can be computed if the absorption coefficient is given. Reference 2 gives the absorption coefficient for high energy gammas as 0.53 cm.$^{-1}$ in lead and for fast neutrons in water as 0.125 cm.$^{-1}$. The attenuation equation for a beam of neutrons in water is thus: attenuation factor, $N/N_0 = e^{-0.125x}$ where N = the number of neutrons escaping from the shield, N_0 = the number of neutrons entering the shield, and x = water thickness in cm.

Similarly, the attenuation equation for gammas in lead is $N/N_0 = e^{-0.53x}$ where N, in this case, refers to gamma rays, and x to the thickness of lead. Equating these general equations to the required attenuation factors, $e^{0.125x} = 2 \times 10^8$ and solving for x, the required thickness of water is 153.5 cm. H_2O, or 60 in. Similarly, solving $e^{0.53x} = 1.17 \times 10^7$ gives a lead thickness of 30.3 cm., or 12 in.

Before these thicknesses can be translated into shield weights, the reactor core size must be known. A 3-ft. radius core for a reactor power of 90 megawatts may be postulated.[2] This represents a reactor power density of about 0.8 megawatt per ft.^{3}. That is, each cubic foot of reactor core can generate 0.8 megawatt of heat. This power density is about 100 times greater than that for the stationary reactors that are described in the unclassified literature. It is interesting to speculate as to whether this is a realistic factor by comparing the power-to-weight ratios of stationary internal combustion engines with those designed for aircraft propulsion. Here we find a similar difference. Stationary plants have a weight-to-power ratio of about 100 lbs. per brake horsepower as compared to approximately 1 lb. per hp. for aircraft power plants. This is certainly not a conclusive argument. It merely purports to show that, for one type of power plant, the internal combustion type, there is an improvement in one of the important parameters of 100 to 1 from stationary plants to power plants designed for aircraft, and that a similar improvement in nuclear power plants is, perhaps, possible. For the 100,000-lb. airplane being investigated and for the assumed power density of 0.8 megawatt/ft.^{3}, the reactor core diameter is 1.44 ft. The weight of lead which is placed around the core is $4/3\ \pi\ (2.44^3 - 1.44^3)\ 705 = 34{,}000$ lbs. The weight of the water is $(4/3)\ \pi\ (7.44^3 - 2.44^3)\ 62.5 = 101{,}000$ lbs. The total shield weight is thus 135,000 lbs., or 35,000 lbs. more than the assumed weight of the airplane. Generally, for the conventional aircraft design being considered here, the structural weight plus all the engines, crew, controls, accessories, etc., add up to about half the design gross weight. The other half is distributed more or less equally between cargo and fuel. Thus, if the nuclear airplane is to compete successfully on a payload to gross weight ratio basis with conventional designs, the reactor and shielding cannot exceed 25 per cent of the design gross weight. For the case shown here, a gross weight of 100,000 lbs., the nuclear reactor is simply too heavy, and the airplane cannot fly.

Proceeding through the foregoing steps for the 300,000-, the 600,000-, and the 1,000,000-lb. gross weight aircraft produces the results shown in Table II. The eighth column, labeled the aircraft equipped weight empty, is the sum of the reactor shield weight and half the design gross weight. The amount that this sum is less than the design gross weight is the payload, or the useful load-carrying ability.

To determine the effect of increasing the reactor power density, the calculations were repeated for reactor core sizes of one half and one quarter of the volume of those assumed originally. The results are in Tables III and IV, and Fig. 2 shows the reactor shield weights. The equipped weight values from Tables II, III, and IV are shown in Fig. 3. The straight line having a slope of 1 represents the line along which the equipped weight empty is equal to the design gross weight. Thus, the aircraft-equipped-weight-empty values which fall above

RESULTS OF SHIELD AND AIRCRAFT WEIGHT CALCULATIONS

TABLE II

Reactor Power Density = 0.8MW/Ft^3

Aircraft Design Gross Weight	Reactor Power MW	Lead Thickness Inches	Water Thickness Inches	Weight of Lead Pounds	Weight of Water Pounds	Total Shield Weight	Aircraft Equipped Weight Empty Pounds	Payload
100,000	10	12	60	34,000	101,000	135,000	185,000	-85,000
300,000	30	12.9	63.8	71,000	151,000	222,000	372,000	-72,000
600,000	60	13.4	65.5	101,000	191,000	292,000	592,000	8,000
1,000,000	100	13.8	67.7	139,000	215,000	354,000	854,000	145,000

TABLE III

Reactor Power Density = 1.6MW/Ft^3

100,000	10	12	60	24,550	92,400	116,950	165,950	-65,950
300,000	30	12.9	63.8	55,000	131,000	186,000	336,900	-36,900
600,000	60	13.4	65.5	70,100	161,900	231,000	531,000	69,000
1,000,000	100	13.8	67.7	95,300	194,000	289,300	789,300	210,700

TABLE IV

Reactor Power Density = 3.2MW/Ft^3

100,000	10	12	60	18,280	81,000	100,080	150,080	-50,080
300,000	30	12.9	63.8	33,800	111,800	105,600	295,600	4,400
600,000	60	13.4	65.5	49,700	135,000	184,700	484,700	115,300
1,000,000	100	13.8	67.7	66,500	161,000	227,500	727,500	272,500

this line represent configurations which cannot fly. The payload vs. gross weight is shown in Fig. 4.

Discussion of Results

First of all, Fig. 4 shows why the statement is made that nuclear aircraft will be large. From this figure it is obvious that no payload is possible until fairly large aircraft sizes are reached. The basic reason for this is shown in Fig. 2. It is clear from this figure that reactor shield weight is not proportional to reactor power, and, since reactor power is proportional to aircraft gross weight, the percentage of the aircraft weight that must be devoted to shielding decreases as the aircraft gross weight increases.

The benefits of increased reactor power density are clearly shown in Figs. 2, 3, and 4, and it is germane to see just what difficulties are entailed when power density is increased. First of all, packing the same power into a smaller volume implies increased temperatures. Thus, materials which can retain their strength at elevated temperatures are required. In addition, the radiation is released in a smaller volume and the core materials must be capable of withstanding higher radiation levels in addition to higher temperatures. Thus, materials research appears to be the key to obtaining higher reactor power densities.

Obviously, the methods used to arrive at the reactor shield assembly weights and the final aircraft weights are not rigorous and detailed. Certain arbitrary assumptions were made. The general trends, however, are representative of the actual variation to be expected if an accurate and complete design program is performed. This is true, furthermore, for turbojet power plants. The minimum aircraft sizes would certainly be different from those shown for the turboprop case, but the shape of the curves would be unchanged, and the advantages of improved materials for the reactor core would be the same. With these limitations, certain conclusions may be drawn.

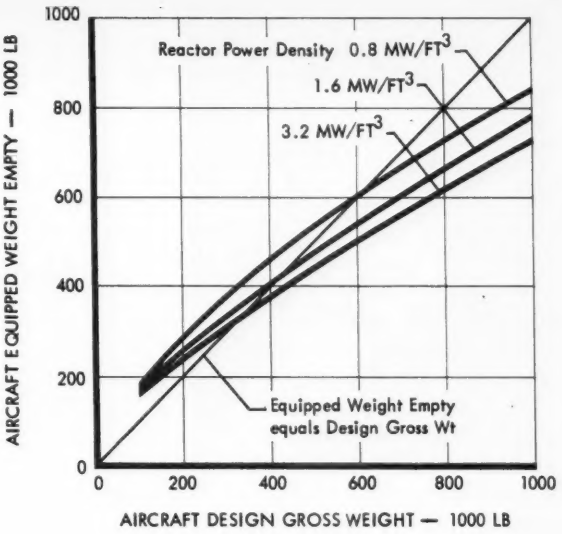


Fig. 3. Aircraft equipped weight empty.

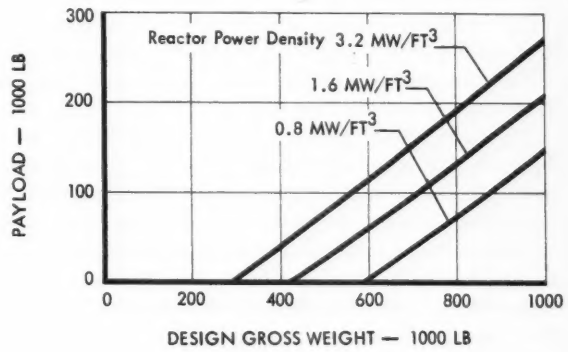


Fig. 4. Aircraft payload.

Conclusions

(1) For a nuclear-powered airplane there is an aircraft design gross weight which is the minimum size aircraft that will just fly and carry no useful load.

(2) This minimum size is rather large by current aircraft standards and is a function of reactor power density.

(3) As aircraft design gross weight is increased, the payload to gross weight ratio becomes larger and eventually approaches the 1 to 4 figure associated with current chemically powered designs.

(4) Increasing the reactor power density by a factor of 2 reduces the aircraft minimum size by one third and, at any value of design gross weight, improves the payload to gross weight ratio.

(5) Increasing the reactor power by a factor of 10 increases the shield weight by a factor of less than 3 for the cases investigated. This is the factor underlying conclusion 3, above.

(6) Improved materials which will withstand high temperatures and massive doses of nuclear radiation will permit a reduction in size of nuclear-powered aircraft.

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✦ ✦ ✦

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Should the Scientist Communicate?

Pertinent to the concern of every aeronautical scientist and engineer are the observations recorded here which, interestingly enough, are those of a Doctor of Philosophy. He follows some of his own advice—and communicates.

As THE ACHIEVEMENTS of science become more numerous, more awe-inspiring, more divorced from the little corner of common sense familiar to all of us, the nonscientist is more and more driven into frustration and defeat as far as any real understanding of the details of his life is concerned. More and more he is reduced to push-a-button-and-have-faith.

A jet plane must be taken with the same faith that a broomstick was some centuries ago. The aerodynamic principles involved in both means of transportation are beyond question.

But from lack of understanding comes fear, and from fear comes hate. If the scientist becomes a creature removed, it is only a step to that of being a creature first mistrusted and then fought.

The simultaneous fear of, and need for, the scientist are creating an increasing tension which is forcing a new and unprecedented crisis on society, one that is sickeningly apparent now and may become overwhelming in the near future.

At a time when the technically trained man is needed in unprecedentedly large numbers, public interest in science is declining. Science courses in secondary schools are decreasing, and those that are given are often of inferior quality. Science teachers are hard to find. Students turn away from science.

Why?

The "difficulties" and "mysteries" of science frighten off students. The low pay offered the science teacher by a public unappreciative and even distrustful of science frighten off the teachers.

Nor can the scientist, who has himself already tackled the difficulties of science and mastered them, who has found the necessary teachers and taught himself what remained, afford to be blasé or smug about his own achievement. It would be dangerous for him to bask in the rarefied air of the intellectual mountain-peaks and watch the struggle in the valley below with an I-did-it-why-can't-they attitude.

Furthermore, the scientist faces a peculiar danger of his own in this weakening of communication. As the years pass and the quantity and variety of research increase, it becomes increasingly difficult for an individual scientist to maintain a firm intellectual grip on the various ramifications of a chosen field of knowledge. Little by little, the "one-mind field" contracts. More and more, the individual scientist becomes dependent on his fellows for any understanding at all of allied fields.

If communication between fields is allowed to weaken without limit, the effect may well be that of a negative feedback on the advance of knowledge. Each sub-sub-sub-discipline, ingrown and hardened into its own mold, will reach self-imposed limits. Only through the partial integration of neighboring (and even not so neighboring) disciplines can progress be resumed. Yet what if, in time, the species grow so far apart as to make cross-fertilization impossible; or at least so infrequent as not to maintain the growth of science?

It seems to me that there are two possible solutions to this problem, one general and one specific. . . .

First, the general solution. The scientist must recognize his responsibility to communicate. He cannot and must not expect laymen and scientists of other fields to come to him or be damned. He must go out to meet them part way or he will be damned with them. Each scientist must do what he can to popularize science in the sense that he must make its content understandable to as many human beings as possible. Granted, he cannot communicate all he knows to any man not trained equivalently with himself. Granted, he can communicate nothing of what he knows to many individuals unequipped by nature or temperament to receive what he would give them. And yet he must convey as much as he can to as many as he can.

(*Continued on page 35*)

The author, an Associate Professor of Biochemistry, graciously has given his permission for publication of excerpts from his foreword to *Thinking by Machine*, by Pierre de Latil. The *Review* also wishes to thank the publishers, Houghton Mifflin Company, Boston.

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Engineering Education and Training by Industry

Aeronautical engineering educational programs currently sponsored by the industry are outlined, and a listing of some of the literature is provided.

CORRECTIVE ACTION necessary to provide more technical personnel in the United States has received wide attention.

The role of education and training in this nationwide effort, as it applies to engineers in general and aeronautical engineers in particular, is of great interest to those of us vitally concerned with the healthy progress of the aeronautical industry.

This paper will delineate some programs under way in engineering education and training and will reference related material. It is the hope of the author that the information will be of value to all having an interest in increasing the number of engineers in training and employment. Most examples will be taken, somewhat naturally, from the aircraft industry. It is acknowledged that educational and training programs are being supported by other industries.

At the National Level

There are many organizations in the United States devoting efforts on a national level toward increasing technical personnel through education and training.

Some are The President's Committee on Scientists and Engineers, The Engineers Joint Council, American Society for Engineering Education, National Aviation Education Council, Aircraft Industries Association, and Institute of the Aeronautical Sciences.

The Manufacturing Chemists' Association[1] is also providing vocational guidance, having announced a program in high schools last fall to stimulate interest in science and technical work. It is the third step in a long-range Association program to help alleviate the growing shortage of scientists and engineers.

The program includes a series of open-end chemistry experiments to provide more interest and opportunity for student achievement in science. The series is free to public, private, and parochial high schools. Initiating the program in 1956 was a series of experiments for general science students at the junior high level; the second phase constituted awards to college chemistry teachers for "inspiring and holding the interest of students in the field of chemistry."

At the Community Level

At the community level, organizations are also doing their best to increase the number of engineers. While the national level organizations can set policy and help formulate programs, it is really the groups at the community level which can reach individual students, parents, and teachers. The various sections of national engineering societies have been the most active in this field. State Departments of Education have also been active in helping in their school programs.[2] The Virginia Advisory Legislative Council made specific recommendations to the General Assembly, which, if followed in all states, would show evident benefits. Their recommendations were:

(1) The quality of science courses and science teaching should be improved in the public schools. To this end, the Department of Education should set up a special program with personnel charged with improving science study.

(2) Better guidance programs should be offered high school pupils, and especially pupils in the eighth grade. There should be a limited program on an experimental basis for the gifted students in science and mathematics.

(3) The state should give assistance to school divisions in the purchase of science apparatus and laboratory equipment.

(4) An advisory committee composed of scientists, engineers, and educators should be set up to consult with the State Department of Education and advise it in planning and carrying out an improved program of instruction in science and mathematics.

(5) The Council of Higher Education should look into the possibility of putting in the cities branches of colleges offering scientific and engineering education.

(6) Greater use of the scholarship and loan fund programs for students in these fields is advised. Better liaison should be established between public schools and colleges so that students would be better prepared to enter college.

Mr. Arata is Chief Project Engineer, Aircraft.

FIG. 1. IAS Regional Student Conferences, 1957.

FIG. 2. Vocational guidance literature.

Two documents should be read by all those interested in this problem, particularly as it relates to the engineering and scientific manpower in Soviet Russia.[3, 4]

FOR POTENTIAL ENGINEERS

For many years the Institute of the Aeronautical Sciences has been interested and active in the preparation of guidance material and the sponsoring of programs to aid potential engineers.

Like most national engineering societies, the IAS sponsors student chapters. Student chapters are a valuable means of giving future engineers a chance to gain knowledge about the profession to which they will soon belong. At the present time there are 73 Student Branches of the IAS, with about 4,000 student members. While each Student Branch has monthly meetings of current interest, their main effort is planning for Annual Regional Student Conferences.

At the university level, the IAS sponsors the Regional Student Conferences. As noted in Fig. 1, eight such meetings were held in the spring of 1957. These regional conferences, usually sponsored by an IAS Section, give university students a chance to present technical papers of their own choosing. Financial and certificate acknowledgments are given to the winners. The winners of these regional student paper competitions have their papers published by the Institute in a single volume each fall. From this group, one graduate and one undergraduate are selected for an overall prize, a bronze plaque.

Fig. 2 shows some of the vocational guidance material that has been issued by the IAS. Of prime interest to potential engineers is the booklet *Your Career as an Engineer in Aviation*. This booklet describes such subjects as planning for an engineering education, requirements for admission to college, selection of an engineering college, engineering job assignments, etc. Over 100,000 copies of this booklet have been mailed to high schools throughout the United States.

Another IAS activity has begun formulation within the last 2 years. It is known as the ECDC (Engineering Career Development Committee). Initially formulated by West Coast Corporate Members of the Institute, it has now blossomed into a national activity with East Coast, Midwest, and West Coast sections. While each ECDC committee is relatively small, Fig. 3 indicates the potential source of membership. The purpose of ECDC is the exchange of corporate information relating to educational efforts and expenditures. As a means of transmitting this information, an ECDC handbook has been prepared for each IAS Corporate Member and other interested agencies.

All 28 IAS Sections sponsor student effort in areas ranging from career clinics to television shows. In one year, it is understood, six Sections put on their own television shows. The Hagerstown Section has had the opportunity to present some aspects of engineering over a series of closed circuit television talks to the Washington County junior and senior high schools. Fig. 4 shows the Washington County, Md., Board of Education television studio facilities.

In addition to Section activity, most Corporate Members of the Institute have programs aimed to help students also. The methods of assistance are quite varied and include Industry Education Days, wherein local teachers are briefed and taken on tours of the manufacturing areas—including final assembly. Visits of this sort permit the teacher to make classroom instruction more interesting, as well as open the inquiring minds of the students. In addition to tours for teachers, visits are arranged for students.

Another service that companies provide is the furnishing of technical personnel to participate in local Career Day programs. These Career Days permit the students to learn first hand about various vocational opportunities. Perhaps the most important support a company can provide is in relation to college and university scholarships.

Another worth-while program for high school students is known as JETS (Junior Engineering Technical Society), begun by the Michigan State University and now adopted by science teachers in a number of high schools. This organization permits high school stu-

dents—as an off-hours activity—to learn, do, and see items relating to science and engineering.

Another area for possible stimulation of potential aeronautical engineers involves model building, design contests, and perhaps even glider flying. One manufacturing company[5] conducted a contest for students in grades 7 through 12 in Trumbull County, Ohio, to select the best sketches showing the entrant's ability to recognize and apply techniques to a practicable and futuristic design. One automobile company—namely, General Motors Corporation—has been providing stimulation in this area for many years by their sponsorship of the Soap Box Derby and the Fisher Body Craftsman Guild.

For Engineering Employees

Companies employing engineers and scientists can help themselves, their employees, and the country by providing tangible encouragement for their engineering employees to further their education. This can be achieved by sponsoring night school and on-the-job training in subjects of vocational undergraduate and graduate level. For students who wish to seek an advanced degree, some procedure for sabbatical leave should be considered.

Another area of engineering growth is to encourage the publication of technical articles and the presentation of technical papers before engineering society meetings.

Conclusion

It has been shown that at both the national and the community levels, there is an awareness of the need to increase the number of engineers and scientists. This awareness has been transmitted into specific programs to achieve the desired results. Technical societies, private companies, and school systems are all contributing to the education and training of the youth of the country. References 6 through 27 are a portion of the source material available relating previous effort by those just mentioned.

Fig. 5 is a tabulation of areas for further education and training aid defined by primary schools, junior and senior high schools, city colleges and universities, and engineers in training. Some areas in Fig. 5 are now well covered while other areas have been partly neglected. It is hoped that individuals and organizations interested in engineering personnel will make an effort to increase the scope of their activities.

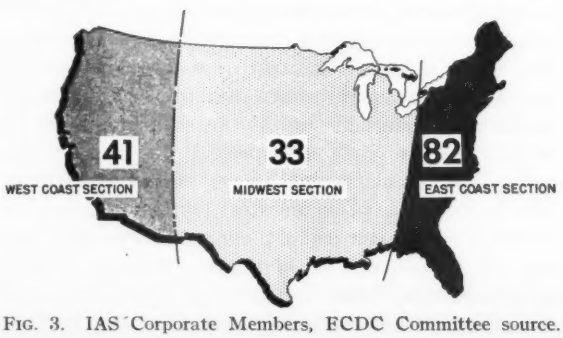

Fig. 3. IAS Corporate Members, FCDC Committee source.

Fig. 4. Closed circuit TV vocational guidance.

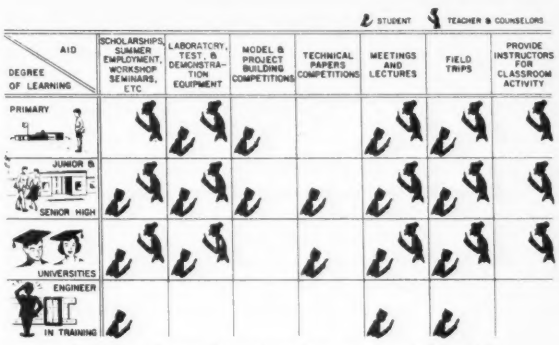

Fig. 5. Areas for education and training aid.

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(*Continued on page 41*)

"The intent of this paper is to clarify the materials selection picture by showing the influence of configuration and design criteria on the choice of materials."

Selecting Structural Materials for Supersonic Flight

Donald D. Cox
Boeing Airplane Company

SYMBOLS

F_{tu}	=	ultimate tensile strength, psi
F_{cy}	=	compression yield strength, psi
ρ	=	density, lbs./cu.in.
N_{gust}	=	ultimate load factor due to gust
Δn	=	limit incremental load factor due to gust
K_g	=	gust alleviation factor
U_{de}	=	equivalent gust velocity, ft./sec.
W/S	=	gross weight/wing area, lbs./sq.ft.
V_e	=	equivalent velocity, knots
a	=	slope of the airplane lift curve, per radian

THERE HAS BEEN much discussion and controversy in recent years on the relative merits of the various steel and titanium alloys for structural material of supersonic aircraft. Much of the controversy stems from an inadequate clarification of the basis for a particular materials comparison study. In many cases the conclusions of a materials comparison study have been based on a specific design, the details of which could not be divulged either because of military security or company proprietary interest. In other cases, the comparison has been made without regard to any specific application. In many cases the conclusions were apparently contradictory. One of the results has been that the aircraft industry has presented a confused and bewildering picture to the military services, the material producers, and to itself. The intent of this paper is to clarify the materials selection picture by showing the influence of configuration and design criteria on the choice of materials.

It will be shown that the configuration and environment characteristics are just as important as the material properties in choosing the correct structural material. It will also be shown that steel construction may be optimum for one design and titanium construction may be optimum for another design even though both designs are subjected to the same maximum temperature.

Mr. Cox is Weight Unit Chief in the Seattle Division.

The scope of this paper will be limited to the structural efficiency considerations of aircraft designed to spend a considerable amount of time in a given thermal environment.

DISCUSSION

The problem of trying to relate the important material parameters into one simple, concise structural index has occupied the attention of many during the recent expansion of the materials-temperature field. None of these indices have been a panacea however, and the strength/weight ratio is still considered to be useful for general comparison studies despite all of its weaknesses and limitations. In this paper, the strength/weight ratio shall be the average of the ultimate tensile strength/density (F_{tu}/ρ) and the compressive yield strength/density (F_{cy}/ρ). This averaging is more accurate for typical air-supported vehicles than if either tension or compression strength/weight ratio were considered alone. While this parameter is adequate for the purposes of this discussion, it cannot be emphasized too strongly that a considerable amount of detailed investigation on each specific configuration is required to obtain an accurate materials comparison.

The strength/weight ratio as a function of temperature for several typical structural materials is shown in Fig. 1. These ratios are based on what is believed to be reasonable values of strength although it is admitted that there is a considerable difference of opinion in industry on even the basic mechanical properties of the newer metals and alloys. One of the newer titanium alloys, 16V-2.5AL, is shown here as it represents one of the more promising alloys that will be available in production quantities in the near future. The titanium alloy 6AL-4V is representative of the high strength titanium alloys that are currently available. The 12 per cent chromium steel (12 Cr) is typical of several of the better medium chromium content steels that are considered for aircraft application. On a strength/weight basis, 6AL-4V has approximately a 35 per cent weight advantage over the 12 Cr steel at

room temperature. This advantage diminishes with temperature until at approximately 600°F. the two materials are of equal efficiency. Above 600°F. the 12 Cr steel has a slight advantage. It will be shown later that many designs capable of operating in a 600°F. environment are actually critical at room temperature conditions and therefore the strength/weight ratios at room temperature may be much more important than the 600°F. strength/weight ratios.

At around 1,000°F. both titanium and steel lose efficiency quite rapidly. It would appear that for structures designed at temperatures of 1,200°F. and above the inconels and molybdenum materials will play a dominant role. The material transition in the future will be not from titanium to steel but rather from the titaniums and steels to the inconels and the molys.

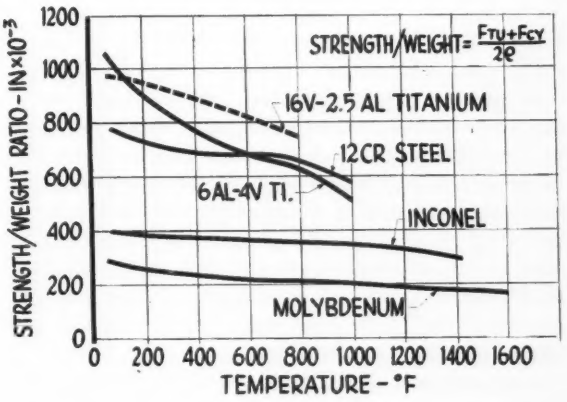
The effect of temperature on material properties is only a portion of a comparison study. There must also be an understanding of how the loads may vary with environmental temperature. The following remarks will be concerned primarily with the inboard portion of the wing structure. The loads discussed will be the axial tension or compression loads in the upper or lower surface which resist the net bending moments.

One of the factors affecting the wing surface load is the spanwise distribution of the air-load forces. This distribution is primarily dependent upon wing configuration, structural stiffness, and Mach Number. For rigid wings, the air-load moment arm, or spanwise center of pressure, is at the maximum outboard location in the transonic region. The amount of inboard movement of the center of pressure with increasing Mach Number is dependent upon the wing leading-edge sweep of the particular configuration. With increasing Mach Number, the load for a highly swept wing decreases only slightly if the wing leading edge is behind the Mach lines. For the case of a wing with less sweep, the load reduction with increasing Mach Number is quite pronounced due to the air-load distribution change as the Mach lines intersect the wing. For the case where $M = 3.5$, the highly swept wing would have only a 3 per cent load reduction whereas the wing with less sweep would experience a 20 per cent load reduction. The effects of aeroelasticity can either magnify or diminish this effect, but, in general, the air-load redistribution due to increasing Mach Number will cause the load to decrease. The amount of decrease will depend upon configuration.

The effect of air loads due to gust may cause the wing surface load to either increase or decrease with Mach Number. Many large airplanes with low design maneuver load factors are gust critical. The ultimate load factor that the structure must be designed for in the gust condition can be expressed as $N_{gust} = (1 + \Delta n)\ (1.5)$ where $\Delta n = K_g U_{de} V_e a/(498\ W/S)$. Since the V_e and a terms are dependent on Mach Number, it is of interest to determine how the load factor varies as the Mach Number is increased. The slope of the lift curve varies considerably with configuration, but, for a given configuration, it has a maximum value transonically and decreases as the Mach Number is increased. The equivalent velocity will increase directly as the Mach Number increases if the altitude remains constant. Increasing the altitude with increasing Mach Number, however, will allow the V_e to remain constant. From this it can be seen that as the Mach Number is increased the load factor due to gust may either increase or decrease, depending upon the Mach Number - altitude placard and the slope of the lift curves.

With the nearly unlimited combinations of configurations, speed, altitude, and load factor that are possible it should be apparent that the load - Mach Number curve can vary in three ways: (1) the load increases rapidly with Mach Number; (2) the load remains nearly constant with Mach Number; and (3) the load decreases rapidly with Mach Number. Loads for three airplanes having these characteristics are shown in Fig. 2.

Airplane A is a low-maneuver load-factor airplane designed to fly at sea level. As discussed earlier, the load factor increases with Mach Number due to gust, and, for this case, the increase is greater than the load decrease that occurs due to change in air-load distribution, reduction in gross weight due to fuel usage, etc. At $M = 2.5$ the load is 45 per cent greater than the transonic load.



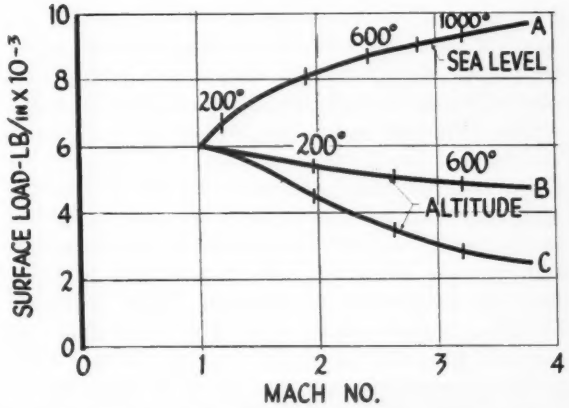


FIG. 1 (*top*). Strength/weight ratio vs. temperature.
FIG. 2 (*bottom*). Typical load vs. Mach Number.

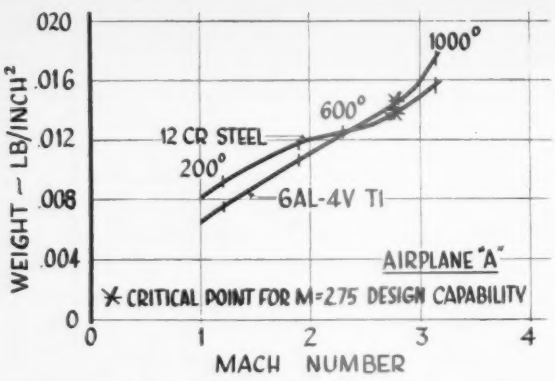


FIG. 3. Weight vs. Mach Number—sea-level design.

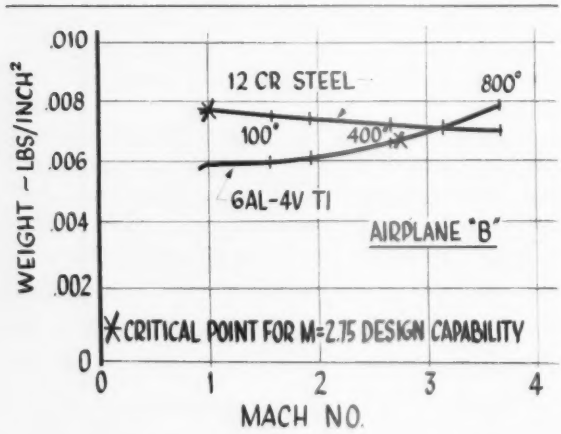


FIG. 4. Weight vs. Mach Number—maneuver critical.

Airplane B is a configuration that is critical due to maneuver loads throughout the design envelope. Typical of this would be a high-maneuver load-factor airplane such as a fighter or a design of such low aspect ratio, high sweep, high wing loading, etc. that it is not gust critical. For this design, the load is nearly constant, being affected by gross weight change, air-load redistribution, and fuel management. For this design, at $M = 2.5$ the load reduction is approximately 15 per cent of the transonic load.

Airplane C is a configuration that is highly gust critical transonically and maneuver critical at high Mach Numbers. A design featuring a low wing loading, medium aspect ratio, low sweep, and a low-maneuver load factor designed to fly essentially a constant V_e placard would have the load-temperature relationship shown. For this design, the load at $M = 2.5$ is 40 per cent less than the transonic load.

The large effect that altitude has on skin temperature at a given Mach Number should be noted. At sea level, the $M = 2.4$ temperature is approximately equivalent to the $M = 3.2$ temperature at altitude. Since the temperature environment cannot be defined by Mach Number alone, it is often misleading and confusing to speak of a design as having a certain Mach Number capability unless the altitude is also stated.

By combining the load-temperature curves of Fig. 2 and the strength/weight-temperature curves of Fig. 1 to obtain a weight-temperature curve, the effect of configuration and design environment on material selection becomes more apparent. Fig. 3 shows the effect of Mach Number and material on the weight of a sea-level critical design. (Airplane A, Fig. 2). The weight is the weight per square inch of the wing surface material. At $M = 1.0$ the required weight for the titanium design is 0.0065 lbs./sq.in. and for the steel design the weight is 0.0082 lbs./sq.in. The titanium advantage decreases as the Mach Number increases until the steel and titanium are of equal weight at about $M = 2.4$ (600°F.). Detailed investigation including thermal stresses, etc. would probably increase the temperature at which the two materials reached equal efficiency. At $M = 2.75$ the required weight for both the steel and titanium design has approximately doubled the $M = 1.0$ requirement showing that for this type of configuration and environment any increase in Mach Number will cause the weight of both the steel and titanium design to increase since the critical design point is at the maximum temperature the structure attains. For an $M = 2.5$ design there would be little difference in the weight of the wing cover material whether the design was of 12 Cr steel or of 6AL-4V titanium since both designs require approximately 0.013 lbs./sq.in. of structure. For a design with $M = 2.75$ capability, both the steel and titanium designs would be critical at that speed with the steel design having a slight weight advantage. A material having a high strength/weight ratio at high temperature is very desirable for this type of design.

Fig. 4 shows the effect of Mach Number, temperature, and material on the weight of a configuration that is maneuver critical. (Airplane B, Fig. 2). The reduction in load with increasing Mach Number is approximately equal to the reduction in strength of the steel, resulting in a nearly constant weight over a broad speed range. The titanium strength has reduced faster than the load has reduced, resulting in an increase in weight as the Mach Number is increased. However, the 6AL-4V titanium design would be 15 per cent lighter than the 12 Cr steel design at $M = 2.75$ since the titanium weight at $M = 2.75$ is 0.0067 lbs./sq. in. compared to the steel design $M = 1.0$ requirement of

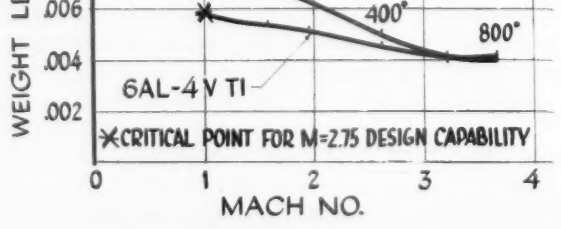


FIG. 5. Weight vs. Mach Number—altitude gust critical.

0.0077 lbs./sq.in. The interrelationship of load characteristics and material characteristics on the critical design point is illustrated here. Assuming a maximum speed requirement of $M = 2.75$ the titanium wing would be critical at that point, but the steel design would be critical at $M = 1.0$.

Many long-range aircraft designs are gust critical in the transonic region. The weight-speed requirement for such an airplane is shown in Fig. 5. This is an airplane having the load-temperature relationship of airplane C, Fig. 2. For designs of this type, an increase in speed does not affect the weight (up to a certain point) since the design is critical in the transonic region. At $M = 1.0$ the titanium weight required to carry the load is 0.0058 lbs./sq.in. At $M = 3.2$ the required weight is only 0.0041 lbs./sq.in. This would result in a large margin of safety at the high temperature condition. Even though the 12 Cr steel weight is approaching the 6AL-4V weight at $M = 2.75$, the titanium design would still be 35 per cent lighter since the weight of the design is determined in the transonic region. A high strength/weight ratio at room temperature is extremely important for this type of design.

To summarize the three previous charts in order to emphasize the importance of configuration and environment on material selection, Fig. 6 shows the critical design point weight of the steel airplane wings relative to the critical design point weight of the titanium airplane wings as a function of Mach Number capability. This chart shows that for a design where the load increases with Mach Number, such as a low-altitude design (airplane A), the advantage of titanium over steel decreases quite rapidly with increasing Mach Number, and steel is lighter at the higher Mach Numbers. For a design where the load is essentially constant with Mach Number, such as a fighter design (airplane B), titanium has an advantage over steel over a broader Mach Number range. At the higher design Mach Numbers where the titanium advantage is low, steel could be chosen over titanium for reasons other than weight considerations. For a design where the load decreases with increasing Mach Number, such as large, long-range aircraft (airplane C), titanium has a decided advantage over a very large Mach Number range. Detailed investigation may modify these results, but the general pattern will remain as shown.

This discussion has been concerned primarily with the weight of the wing surface material, but it should be

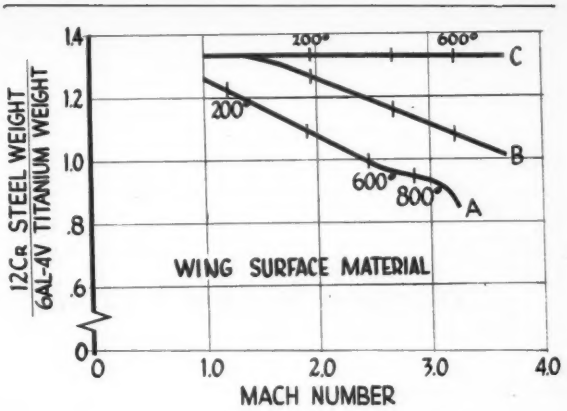


FIG. 6. Relative weight vs. Mach Number.

apparent that other portions of the airplane structure also have characteristics that either increase or decrease the load with increasing Mach Number. It is entirely possible, therefore, that for a given configuration and environment the minimum weight material for the wing could be steel and the minimum weight material for the body could be titanium, or vice versa. It requires a thorough investigation of the design to determine which of several materials would be optimum for the individual structural components.

CONCLUSIONS

The confusion that exists concerning the relative merits of the various steel and titanium alloys for supersonic design has been caused more by a lack of understanding of the application than it has been by a disagreement in basic knowledge. It has been shown that the load in the aircraft structure may either increase, decrease, or remain constant as the Mach Number increases, depending on the specific configuration and environment. It has also been shown that this load-temperature relationship may be just as important as the strength/weight-temperature relationship in the determination of the structural material. Based on the material properties and the load variations as presented, titanium alloys show a considerable weight advantage over steel alloys for a broad range of temperatures and designs. The gains in range and payload that can be obtained due to the increased structural efficiency of the high strength titanium alloys are so substantial that titanium must have a prominent place in our materials inventory.

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"Since the central air data computer supplies information to a number of aircraft subsystems, the overall performance of the weapon system is highly dependent upon the ability of the air data computer to meet all of the system requirements."

Weapon System Requirements for Air Data Computers

A. K. Hammell
Minneapolis-Honeywell Regulator Company

Air Data Computer Specification Characteristics

The ultimate requirement of any airborne weapon system is the successful completion of its mission. Since the central air data computer supplies information to a number of aircraft subsystems, the overall performance of the weapon system is highly dependent upon the ability of the air data computer to meet all of the system requirements.

There are two requirements that must be met by the air data system. The first is a reference type of signal used to define the characteristics of the particular flight condition. This type of signal is used by the pilot for reference or by other subsystems as a computing or gain-variation parameter. The second signal is a dynamic control parameter used as a control or stabilization term. The dynamic control terms require very sensitive transducers with small hysteresis and relatively good dynamic response. Unless the specifications are complete and fully consider all requirements, the system may meet the specifications as written and still fail to provide the required performance.

For several years, dynamic analysis of system performance has been employed in defining the requirements of control systems but has not been as popular in fully establishing input data requirements. As a result, complete specifications for central air data computers are not presently available. While a fairly complete specification may be established by considering the available weapon system requirements, unknown characteristics may affect the weapon system capability.

A very important consideration in air data computer specifications is weapon system reliability. While some parameters may be used in noncritical functions or to improve performance, some quantities are vital to safe operation and the ability to complete the mission. The integration of air data computation requires greater complexity to attain the varied requirements and poses certain reliability problems. An example of this is in the use of altitude information for instrumentation and for an altitude hold mode of automatic flight control. Where a relatively simple mechanical altimeter will provide an adequate reference to the pilot, the flight control system requires a complex and hence somewhat less reliable electromechanical device to attain the necessary sensitivity and dynamic response. The integration of these functions into a single device may lead to some degree of compromise.

This paper was presented at the U.S. Navy Bureau of Aeronautics Symposium on Air Data, Cornell Aeronautical Laboratory, Inc., Buffalo, N.Y., September 24–26, 1957.

Mr. Hammell is an Assistant Project Engineer, Autopilot Analysis.

System Requirements

In order to define the specifications of the central air data computer, each subsystem must be considered. The following discussion of air data requirements includes typical requirements and general comments for several subsystems. However, since specific systems may have unique characteristics, these requirements cannot be considered as a complete and general case.

Air Data Display Output Requirements

Probably the most basic use of air data information is for display to the crew. Although most current display instruments do not use air data computer information, it is quite probable that display requirements will be imposed upon the central system to obtain complete integration of all air data computation as reliability and fail safety of the air data computer are proved. Complete integration will provide many advantages to the weapon system by eliminating redundant transducers and instruments.

The requirements imposed upon the central air data computer by the display system fall into two distinct areas. The first is for the reliability of minimum information required for safe flight so that under the most severe conditions the pilot would be assured of adequate information to make a safe return to base. Specifications for the emergency display of indicated air speed, altitude, Mach Number, and rate of climb would be

quite arbitrary because exact minimums cannot be defined.

The second type of display requirement is concerned with the presentation of information necessary to attain the best mission performance. Bombing, rendezvous operations, and vertical separation require extremely accurate display of basic air data information in order to be consistently successful.

Based upon the ability of the pilot to read instruments, accuracy on the order of 1.0 per cent is desirable for Mach and altitude display while 2.0 per cent accuracy on indicated air speed is adequate. Rate of climb (while not requiring extreme static accuracy) has several problems because of the wide ranges that are encountered. To be useful to the pilot, rate of climb must be reasonably accurate at fairly small rates on the order of 50 to 100 ft. per min. while being capable of sensing values up to 80,000 ft. per min. In addition to the basic pilot display requirements, true air speed with 1.0 per cent accuracy should be presented to the navigator for navigation and attack operation.

While the maximum speed of combat aircraft is increasing, the requirement of control at low speeds remains and, in fact, is becoming more critical. Loiter and saunter modes as well as the approach and landing conditions require accurate handling to maintain satisfactory minimum speeds without approaching the stall limits too closely. A significant reduction in landing speed should be attained with angle-of-attack information that is accurate to within 0.5°. Angle of attack is superior to indicated air speed because it provides an indication of the proximity to stall that is quite independent of aircraft loading conditions.

One aspect of display requirements that has not received much attention is that of response time. If a pilot desires to control the aircraft to a given air data parameter, the precision of control is somewhat proportional to the speed of response of the parameter display. In addition, the percentage of time that the pilot must devote to control is increased for larger time lags. Since most of the lag in air data systems is contributed by the pressure lines and volumes, any developments in the air data computer that will minimize these lags is highly desirable.

Air Data Computation Requirements

As greater automaticity is necessary to perform complex missions, requirements are placed upon the air data system to provide accurate data for the various subsystem computers. Fire control, bombing, navigation, and energy management computers, and the engine control, flight control, and inlet diffuser systems are all potential users of air data information.

As is the case in all computation, the accuracy of the results is dependent upon the accuracy of the input data. Some computing functions do not require high accuracy and can be considered as noncritical. An example of these is the use of air data quantities as gain variation parameters in the flight control and stability augmentation systems. While certain accuracy is required in each case, it is much less than that required by other computing systems.

The fire control computer is highly dependent upon accurate air data to compute the trajectory and the weapon release point of ballistic type weapons. For these computations, angle of attack with present accuracy of about 0.5° is the major contributor to system errors. Significant system improvement can be attained by improving static accuracy to 0.1°. The accuracy requirements for sideslip are the same as those of angle of attack. Since the aircraft possesses weathercock stability which will turn the aircraft into the relative wind more accurately than sideslip can presently be measured, the use of a sideslip parameter in jump angle computation will not be beneficial until precise accuracy within 0.1° is attained.

The requirements for computing accuracy throughout the weapon system are dependent upon the mission and configuration of the system. In many cases, it appears that computing requirements may become less stringent because other systems are replacing or relieving the need for accurate air data as a computing parameter.

In the past, air data has been used as a substitute for inertial and earth coordinate information, but, as new developments have made this information available, some requirements for air data can be dropped. In considering the direct applications for air data, it is apparent that air data information defines only the conditions about the aircraft with no absolute reference to the earth or space. With this in mind, the primary use of air data would be for the following:

(1) Aerodynamic use such as stability and control and optimum flight programing. These are cases where the performance is completely dependent upon air data.

(2) Comparing true air speed with ground speed to determine wind velocities. This would require very high static accuracy of the true air-speed signal.

(3) For vertical separation and rendezvous operations where pressure altitude is a common reference for the various aircraft.

The inertial platform handles navigation problems and provides reference information for fire control and bombing computers. A guided-missile weapon eliminates the requirement for precise ballistic computation. Most of the remaining uses are for noncritical gain scheduling and programing functions.

Obviously there are weapon systems configurations which could require extremely precise air data inputs, and the only way to define the requirements is to consider the specific system.

Air Data Flight Control Requirements

Static accuracy is the primary requirement for display and computing functions, but the use of air data as a dynamic control parameter requires high sensitivity and linear dynamic response characteristics. Mach

and altitude control modes of the flight control system are the most common examples of controlling to a given air data parameter.

The requirements for control data are somewhat incompatible with the static accuracy requirements as far as the air data system is concerned. As an example, altitude control requires an extremely sensitive and linear dynamic response for very small amplitude deviations from the reference. This requirement, coupled with the wide range of altitude encountered, makes it very difficult to obtain good static accuracy over the 80,000-ft. range. The requirement for sensitive and linear signals is not obvious until the overall system requirements are considered.

A typical altitude control specification calls for control to within 10 ft. of the reference at sea level or an equivalent pressure difference at altitude. This means that static pressure is to be maintained to within 0.7 lbs. per sq.ft. of the reference. The airframe and flight control system may be considered as a closed loop dynamic system with altitude error as an outer loop. The transfer function of such a system is fourth order in the most linear case and is very susceptible to sustained small amplitude oscillations when the control loop contains elements with threshold and hysteresis.

Experience has shown that the gains required for control within specifications cause sustained oscillations due to the nonlinear dynamics of the altitude signal. The amplitude of the oscillation must then be less than ± 0.7 lbs. per sq.ft. which requires the hysteresis and threshold effects to be well under this value. Although problems associated with dynamic response have been recognized in automatic flight control systems for several years, static accuracy with little concern for dynamics has been the basic requirement incorporated into central air data computer specifications. Since fixed numbers for the allowable hysteresis and threshold cannot be established for a complex electromechanical system with distributive elements, some current requirements state that the phase lag of the system output shall not be greater than 10° for a sinusoidal input of ± 10 ft. at 0.25 cps. While this specification may be more severe than necessary for some systems and not severe enough for others, it is an attempt to specify a requirement that has not been fully recognized.

Since altitude rate and Mach rate signals may be used as stabilization feedback terms, the sensitivity is an important factor. As an example, the typical period for Mach or altitude control is about 30 sec. Assuming control accuracy of ± 10 ft. for altitude control with sinusoidal variations, the peak rates experienced will be ± 2 ft. per sec. To provide sufficient damping for small amplitude oscillations, the sensitivity should be on the order of one tenth of the peak rate. Thus, the altitude rate signal should be sensitive to 0.2 ft. per sec. in order to be of any use as a stabilization term. The sensitivity for Mach rate signals under similar conditions is 0.002 M/sec. to keep residual oscillations within ± 0.01 Mach. Good sensitivity and accuracy of altitude rate signals have been found necessary for some automatic landing and flare-out systems.

The efforts to increase the performance capabilities of combat aircraft have resulted in many stability problems, some of which are directly related to safety of flight. Long slender bodies bring out inertial coupling problems and small vertical tail surfaces reduce directional stability, both contributing to the fact that the aircraft cannot be safely flown in certain conditions without using a stability augmentation system. Both angle-of-attack and sideslip information may be required by stability augmentation systems to maintain good stability through the entire flight range of the aircraft. Both terms would be used in the augmentation of the aircraft's short period dynamic characteristics and, as such, would require good dynamic performance with high reliability. Angle of attack may be used to minimize the yaw-pitch coupling problems which would not require extreme accuracy. In addition to providing directional stability, sideslip would probably be used for steady-state coordination of the aircraft which requires static accuracy on the order of 0.05°. Until accuracy of this order is attained, lateral acceleration will probably be used although the use of sideslip information is desirable.

General System Requirements

Until now, consideration has been given primarily to the overall requirements that the various subsystems impose on the central air data computer. However, there are general requirements that must be considered as a part of the responsibility of the air data system. Errors in the static pressure system due to angle of attack and Mach Number and the pressure lags due to the physical characteristics of the pressure lines contribute special problems that must be solved. The air data requirements are referenced to the actual conditions rather than those sensed by the air data transducers. Consequently, adequate compensation by the computer must be included to meet the static and dynamic performance requirements. Static pressure errors are very difficult to define accurately without extensive flight test which is very late in the air data computer program. From this standpoint, it is very desirable to have a flexible compensation system which can be altered to achieve correct compensation.

Since angle of attack and Mach Number are part of the airframe short period dynamics, either of these terms can seriously effect the stability when introduced through the control feedback loops. If the compensation system is not capable of providing adequate dynamic compensation, the effect is the same as if someone added unknown feedback loops into the control system.

Angle-of-attack and sideslip sensors are susceptible to errors because of changes in the local airflow due to Mach Number. Generally, these errors induce a bias to the output which affects the static accuracy of the signal. While the amount of error varies with Mach

Number, most installations do not have much change in the error for small Mach variation and thus, dynamic coupling effects can generally be considered negligible.

Conclusion

The requirements imposed upon the central air data system by the weapon system are quite severe from the standpoint of static accuracy and dynamic response, although definite specification cannot be made without considering the weapon system and the mission requirements. Without a thorough study of the weapon system requirements, efforts may be misdirected in attaining extreme accuracy when it is unnecessary while overlooking some critical characteristics.

The requirements for display to the crew are concerned primarily with static accuracy and reliability. The accuracy requirements are based upon the ability to display information to the pilot in a form that can be easily interpreted. An attempt to provide extreme resolution on displays may tend to confuse the pilot or make it impossible to read at a glance. In addition, pressure altitude is not an accurate measure of height and extreme accuracy is meaningful only when considered as a reference for different aircraft in the same vicinity. Extremely high reliability is necessary for the basic display parameters to maintain safety of flight.

The requirements for air data to be used in the various computers in the weapon system are highly dependent upon the mission and the system configuration. Fire control systems with ballistic armament appear to have the most stringent requirements. There is some indication that weapon system advancements are making computational requirements less stringent. The use of guided weapons reduces the need for precise control and computation, and the availability of more appropriate signals, such as ground speed for navigation from the inertial system, eliminates some requirements completely.

The major requirement for control systems is for high sensitivity and linear dynamic response. While reduced accuracy in display and computing systems may deteriorate the performance, excessive nonlinearities in control loops will result in complete instability of the system. Up to the present, the need for adequate dynamic requirements has not been reflected in central air data computers. A thorough analysis of the dynamic requirements must be made to define adequate dynamic specification for air data computers.

Specific problems such as yaw-pitch coupling can present safety-of-flight problems unless the air data information supplied to the stability augmentation system has the required dynamic response characteristics. In order to adequately appraise these problems, dynamic analysis involving the nonlinear characteristics of the air data signals is necessary.

✦ ✦ ✦

Should the Scientist Communicate? *(Continued from page 24)*

To scientists outside the field, the popularization, even in its simplification and incompleteness, may stimulate a new understanding of one's own field in the light of a neighbor's, with satisfying and fertilizing consequences. To a young student, it may mean an increased interest that will encourage him, perhaps, to turn to science as a career. To anyone at all, it may mean the increased comfort and peace of mind that even a little bit of new understanding often brings.

The specific solution involves, to my way of thinking, the rational development and application of cybernetics and automation. As technology becomes more intricate, an ever larger per cent of human mental effort is directed toward paper work and red tape—the keeping and correlation of records, the preparation and filing of statistics, in short, all the routine that is required to direct the machinery man has created.

With cybernetics and automation taking over the routine uses of human mind, the intellect, freed from routine, can tackle, with that much greater concentration of effort, the creative aspects of mental activity. The intellect can be turned to the task of strengthening the lifeline of communication and of pushing back more speedily still the boundaries of the unknown so that the threat of intellectual stagnation, with all the ills that it would bring upon us, can be, if not removed completely and forever, at least shoved far, far into the future.

Ten years have brought us from speeds of about 600 miles per hour to speeds above 2,000 miles per hour and to altitudes above 126,000 ft. in piloted research aircraft.

THE RESEARCH AIRPLANE
Past, Present, and Future

Walter C. Williams and Hubert M. Drake
NACA High-Speed Flight Station

THE RESEARCH airplane program was initiated in 1944 by the NACA and the Military Services with the letting of contracts for the X-1 and D-558-I airplanes. Since that time the program has progressed to a point where speeds greater than 2,000 miles per hour and altitudes up to 126,000 ft. have been obtained. This is an increase by a factor of about four in speed and two in altitude over the maximum values that existed before the initiation of the research airplane program. It appears that, on the tenth anniversary of the first X-1 supersonic flight, it would be timely to review the history of the program, discuss some of the present problems, and take a brief look at what the future may hold for the manned research airplane.

There have been two general categories of aircraft obtained in the research airplane program: (a) those obtained to effect an exploration in new areas of performance, and (b) those obtained to explore the effects of configuration. The airplanes in the program that fall in category (a) are the X-1, D-558-I, D-558-II, X-1A, X-1B, X-1E, and X-2. Those obtained to investigate configuration effects were the X-3, X-4, X-5, and XF-92A. These aircraft were flight tested at the NACA High-Speed Flight Station at the Air Force Flight Test Center, Edwards, Calif.

Seven of the research airplanes are shown in Fig. 1. Although none of the airplanes shown is being operated currently, the Bell X-1B, which is identical to the X-1A shown, is presently in active use. The X-1B differs from the original X-1 series by having a projecting canopy and a fuselage longer by 4.6 ft. It also incorporates a low-pressure propellant system of greater capacity than the original X-1 series. Continuing clockwise around the figure, the next airplane is the Douglas D-558-I which was obtained as a back-up for the X-1. Next we have the Convair XF-92A which was used in exploring the transonic characteristics of the delta configuration. Opposite the XF-92A is the Bell X-5 variable-sweep airplane, used to explore the effects of sweepback angles from 20° to 60°. The Douglas D-558-II shown next is a 35° swept-wing airplane of which all-rocket and jet-plus-rocket versions were operated. Continuing, we have the Northrop X-4 semitailless airplane and in the center the Douglas X-3 which was obtained to investigate the characteristics of a low-aspect-ratio, straight-wing configuration suitable for flight at a Mach Number of 2.

Table 1 lists the various research airplanes that have been employed in the research airplane program together with the manufacturer, procuring service, and performance figures. In some cases several airplanes of the same type were procured, but only the aircraft which were utilized in NACA research programs are tabulated. Fig. 1 illustrates all the airplanes listed except the original Bell X-1 and Bell X-2, which are familiar to all, and the X-1E. The X-1E may be somewhat unfamiliar so a word of description might be given, particularly since it is one of the research types presently being operated. The X-1E might be described as a somewhat modernized X-1. It is actually the X-1-2 airplane modified to incorporate a projecting canopy, a low-pressure fuel system of increased capacity, and a

FIG. 1. Seven of the research airplanes.

The authors are Chief and Aeronautical Research Engineer respectively.

4 per cent thick wing with aspect ratio 4 constructed by Stanley Aviation Corporation.

Of the 14 airplanes listed, three (the D-558-I-1, X-1A, and X-2) were lost in research operations. These accidents cost the lives of NACA pilot Howard Lilly in the D-558-I and Air Force pilot Capt. Milburn Apt in the X-2. All the remaining airplanes have been retired except the X-1B and X-1E which are still being operated. It might be of interest to mention that thus far about 850 research flights have been performed with these airplanes; 390 of these flights were made with the rocket-powered machines.

Although the maximum performance attained by the various airplanes is of considerable general interest, the meat of the research airplane program, and its very reason for existence, has been the obtaining of research information particularly in performance and lift regions which contemporary airplanes or wind tunnels were incapable of penetrating. The most outstanding example of this function is the original X-1, D-558-I, and D-558-II aircraft which were procured for the purpose of obtaining large-scale data in the region of a Mach Number of 1. At that time, the research airplanes were virtually the only tools available which could obtain these data under the desired conditions. Some of the individual research items that have been, and are being, investigated are listed in Fig. 2. Most of the items are self evident and only a few will be discussed in any detail.

One of the important uses of the research data obtained in this program has been the validation of the ventilated-throat transonic tunnels during their development by NACA. As with all new research equipment, it was necessary to have basic data for comparison in order to insure that there were no unforeseen errors in the basic development. When operation of the transonic tunnels was begun, the research airplane program had full-scale data available in the region of a Mach Number of 1 with which to check the tunnel data.

TABLE 1

TABULATION OF RESEARCH AIRPLANES

AIRPLANE	CONTRACTOR	PROC. SERVICE	M_{max}	$h_{p_{max}}$	FLIGHT RESEARCH
X-1-1	BELL	A.F.	1.5	70,000	1946 - 1950
X-1-2	BELL	A.F.	1.2	55,000	'46 - '51
D-558-I-1	DOUGLAS	NAVY	≈1.0	45,000	'47 - '48
D-558-I-2	DOUGLAS	NAVY	≈1.0	45,000	'49 - '53
X-4	NORTHROP	A.F.	.94	40,000	'48 - '53
D-558-II-1	DOUGLAS	NAVY	2.0	83,000	'48 - '56
D-558-II-2	DOUGLAS	NAVY	1.3	45,000	'50 - '56
XF-92A	CONVAIR	A.F.	≈1.0	45,000	'51 - '53
X-5	BELL	A.F.	1.1	50,000	'51 - '55
X-3	DOUGLAS	A.F. & NAVY	>1.1	40,000	'52 - '56
X-1A	BELL	A.F.	2.5	90,000	'53 - '55
X-2	BELL	A.F.	>3.0	126,000	'52 - '56
X-1E	NACA, BELL, STANLEY	A.F.	>2.0		'55 →
X-1B	BELL	A.F.	>2.0		'56 →

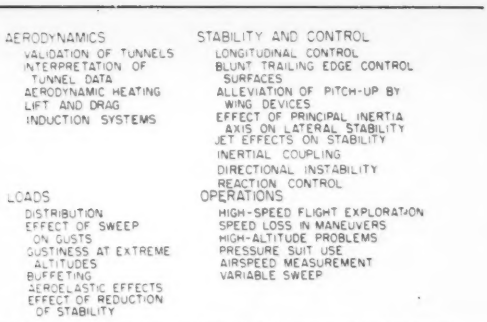


FIG. 2. Problems investigated with research airplanes.

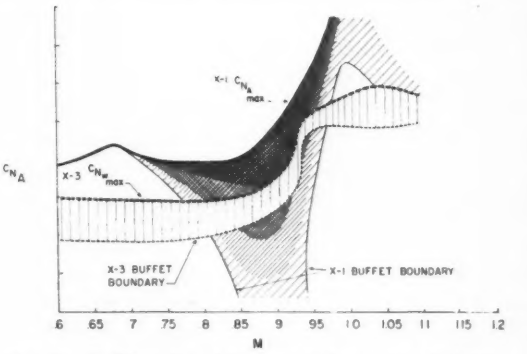
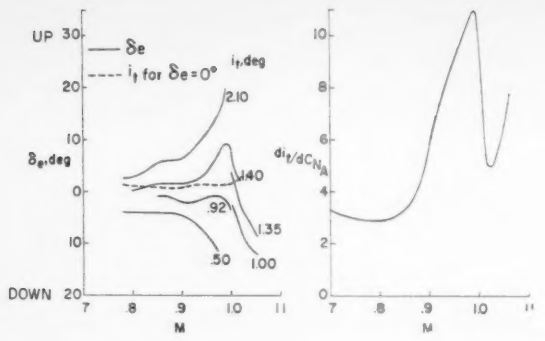


FIG. 3. Buffet region of X-1 and X-3 research airplanes.

The subject of lift and drag is, of course, of considerable interest because it directly affects the performance of aircraft. The research airplane program in this field has involved the determination of Reynolds Number effects, effects of sweep, area-rule modifications, and interpretation of tunnel results.

One of the most annoying problems at the beginning of the research airplane program was buffeting. The rocket research airplanes such as the X-1 were ideal for investigation of this problem because they possessed sufficient power and control to explore the entire buffet region and thus present the first detailed picture of the buffet-intensity variation with Mach Number and lift. Fig. 3 shows a general comparison of buffet characteristics of the X-1 and the X-3 airplanes. The buffet boundary for the X-1 with a 10 per cent thick wing is shown as determined by research instrumentation. In the region between the lines, the buffet intensity is indicated by the shading, increasing from a very mild incipient buffet at the boundary to an extremely intense buffet near maximum lift. The most severe buffet region occurs near a Mach Number of 0.90. These buffet characteristics have been alleviated to a great extent by reducing the thickness of the wings. This is illustrated by the X-3 characteristics which are superimposed on the X-1 chart. The X-3, which has a 4.5 per cent thick wing of low aspect ratio, has a buffet boundary (shown by the lowest dashed line) which exhibits no decrease in magnitude of airplane normal-force coefficient at transonic speeds. The X-3 buffet



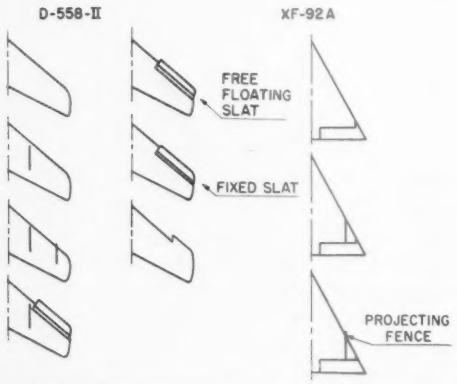


FIG. 4 (*top*). Elevator trim and stabilizer effectiveness X-1. $C_{N_A} = 0.3$.

FIG. 5 (*bottom*). Pitch-up fixes investigated in flight.

is mild between the boundary and the line shown for maximum wing lift.

Under the general heading of stability and control there are several items that should be mentioned. One of the first stability and control problems encountered on the X-1 flights was that of trim changes and loss of longitudinal control at high subsonic speed. Fig. 4 illustrates trim curves obtained at various stabilizer settings for the X-1, corrected to a constant normal-force coefficient. These data show that if stabilizer settings above about 1.5° or below 1.0° are used, the elevator could not trim the aircraft through the speed range to Mach Numbers above 1. Analysis of the data indicated the primary cause of this effect was the great loss of elevator flap effectiveness in this speed range. Such a loss had been foreseen in the design stages and the X-1 had been provided with an adjustable stabilizer for control in this region. The trim curve for this control is shown by the dashed line. The other portion of Fig. 4 shows the variation of stabilizer effectiveness with Mach Number. It might be mentioned that the elevator at a Mach Number of 1 was only 1/20 as effective as the stabilizer. This loss of elevator effectiveness has resulted in the general adoption of all-movable tails on high-speed airplanes.

One of the most persistent problems which evidenced itself early in the research airplane program and which has since been plaguing high-speed service aircraft is the pitch-up which results from pitching-moment characteristics that are nonlinear with angle of attack, or speed, or both. This discussion will be restricted to the case of nonlinearity with respect to angle of attack. The D-558-II, and later the X-4, X-5, and XF-92A, encountered behavior of this type. The wind-tunnel tests indicated the nonlinearities, but techniques for interpreting these nonlinearities in terms of tolerable handling qualities had not been developed. A number of devices were tried on the D-558-II and XF-92A, as shown in Fig. 5, in an attempt to alleviate the violent pitch-up behavior. Each of the illustrated devices, according to the wind-tunnel tests, reduced the magnitude of the nonlinearity; however, these effects were in general not apparent in the motions of the airplane. (Perhaps it should be noted that only wing fixes were tried, since it was not practicable to change tail location.) These flight results, and the strong opinions of the pilots that pitch-ups of this nature were intolerable, stimulated the development of dynamic analytical techniques which, when applied to wind-tunnel test results, have given good correlation with the flight motions.

The problem of coupling between the lateral and longitudinal motions was encountered on the D-558-II and X-4 airplanes during 1951 and 1952. The motion was not dangerous, being rather mild, but was very objectionable to the pilots in that it was continuous. In the case of the X-4 the overall behavior was aggravated by the extremely low damping of the tailless design.

A coupling problem of a different order of magnitude was encountered late in 1954 with the X-3 and slightly later with the F-100A airplane. This is the problem variously termed roll coupling, inertial coupling, or roll divergence. It is characterized by a divergence in yaw or pitch which occurs when the airplane average roll rate exceeds the natural frequency in pitch or yaw. Fig. 6 shows one of the first occurrences of coupling on

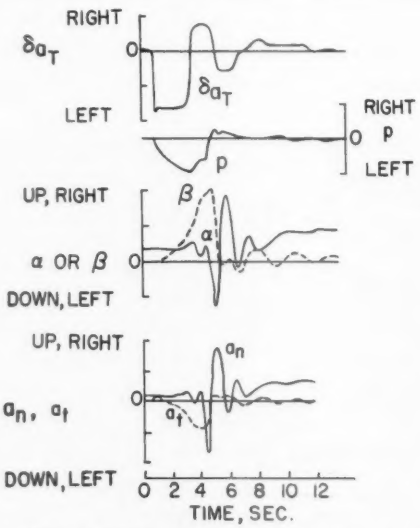


FIG. 6. Time history of X-3 aileron roll. M = 1.05, altitude = 30,000 ft.

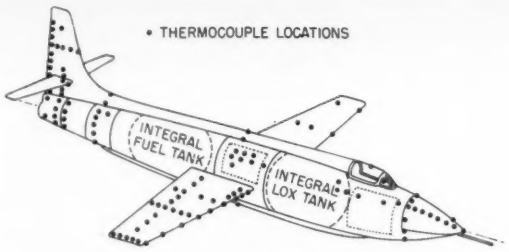


FIG. 7. X-1B temperature instrumentation.

the X-3. As is shown, very large motions can occur because the airplane in this condition is essentially unstable and has a disturbing input of large magnitude. The X-3, in the example, attained load factors which effectively completely demonstrated the structure, all in a period of about 1 sec. It is obviously of extreme importance to understand the basic causes of this behavior and to determine means of avoiding its occurrence. As a result, a great deal of effort has been expended in the past 2 years at the High-Speed Flight Station, as well as many other laboratories, in investigating this behavior.

At present, the X-1B and X-1E airplanes are being operated by the NACA at the High-Speed Flight Station. A few words might be said with regard to some of the problems under current investigation with these airplanes. One problem area is aerodynamic heating. Although these airplanes cannot attain speeds and durations sufficient to cause an appreciable weakening of the structure, much useful research can be carried on in this field. Among the subjects being investigated are the flow of heat into and through the structure, the effect of internal heat sources and sinks, and the effects of boundary-layer transition and aerodynamic interference. Fig. 7 illustrates some of the surface temperature instrumentation installed on the X-1B for this program. About 300 thermocouples are installed on the airplane surfaces and throughout the structure, particularly in the areas of the nose, near the liquid oxygen tank, in the wing, and in the tail surfaces. Much of the aerodynamic heating data obtained on the flights of the X-1B has a direct bearing on future research airplanes such as the X-15.

An important stability problem presently receiving considerable attention is the familiar reduction and loss of directional stability as Mach Number is increased supersonically. This reduction, of course, results from the loss of lifting efficiency by the vertical tail at supersonic speed combined with the relatively constant unstable moment of the fuselage. The reduction of directional stability is of particular interest in flight testing because it is only manifested to the pilot in a very treacherous manner. This is illustrated in Fig. 8 in which the variation of directional stability at trim (α_1) with Mach Number is shown at the top, while the lower portion of the figure illustrates the variation of the period of the lateral oscillation for altitudes of 40,000 and 70,000 ft. The period is the pilot's only indication of the actual level of stability; however, as the figure indicates, the increase in dynamic pressure as Mach Number is increased offsets the tendency of the period to lengthen with decreasing stability until the stability is extremely low. It might be noted that at lower altitudes the relatively constant period is retained to higher Mach Numbers, resulting in a considerable reduction in the warning margin. A particularly dangerous condition exists if a dive is performed to extend the Mach Number range of the airplane. In this case, as illustrated in the figure, the period actually decreases, indicating an increase of stability to the pilot, then abruptly starts to increase as the stability becomes dangerously low. If the airplane is not disturbed at this point, the pilot may be completely unaware of the dangerous condition until it is too late. The danger of this maneuver is even greater as a result of the tendency of conventional airplanes to suffer a reduction of directional stability at elevated angles of attack as indicated by the curve α_2. The normal dive pull-out can then produce an extremely abrupt directional divergence, as shown by the short dashed line.

This reduction of stability has been experienced on all the supersonic research airplanes and a testing technique for flight research in this region has been developed. This technique consists generally of preceding flight test with analog calculations using flight checks on the derivatives employed. These calculations include violent rolling and pitching maneuvers which are used to determine a red-line speed beyond which it is not believed safe to proceed.

Research airplanes such as the X-1B and X-1E, can attain altitudes and speeds at which the conventional control surfaces are ineffective. In this case, reaction controls utilizing either small rockets or the conservation of angular momentum of rotating masses must be provided to obtain the desired orientation. The need for these reaction controls makes it necessary to investigate the handling qualities requirements for such unconventional controls and to determine their propellant requirements. At the High-Speed Flight Station an investigation of such rocket controls has

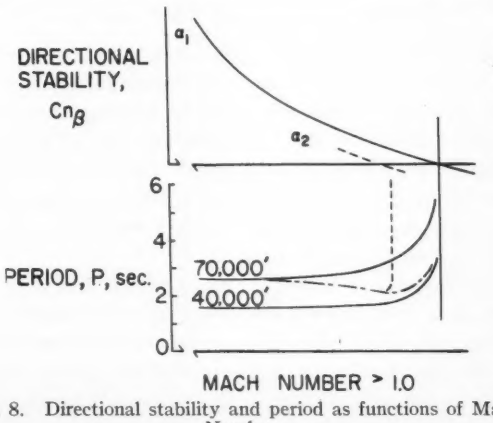


FIG. 8. Directional stability and period as functions of Mach Number.

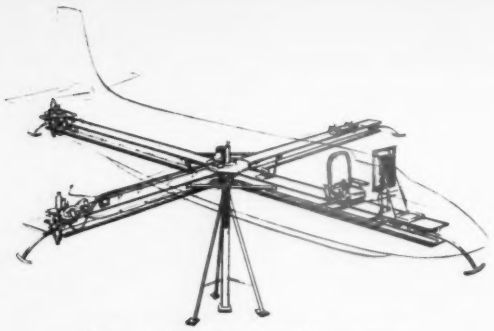


FIG. 9. Reaction control simulator.

already been initiated. The investigation consists of three phases: an analog investigation, a ground simulator study, and flight test. Fig. 9 illustrates the ground simulator which has been constructed to simulate the inertia distribution and geometric proportions of the X-1B airplane. The roll rockets are installed on the right tip and the pitch and yaw rockets are mounted at the tail. The simulator is pivoted at the center of gravity with freedom in pitch, roll, and yaw under the control of the pilot who normally would occupy the cockpit under a hood. The flight research portion of this program is being performed on the X-1B to investigate the use of these rocket controls at high altitudes.

Considering future high-speed research airplanes, some of the obvious problems which affect design and piloting and demand research are listed below.

Design Problems:
- Aerodynamic heating and heat transfer
- Aerodynamic interference
- Aerodynamic efficiency
- Structural design
- Survival

Piloting Problems:
- Poor landing configuration
- Large acceleration
- Reaction controls required
- Large changes in control effectiveness
- Large changes in stability
- Inertial coupling
- Presentation of piloting information

Most of these problems are interrelated—for example, the subject of aerodynamic interference has a considerable bearing on the aerodynamic heating and aerodynamic efficiency of a hypersonic design. The aerodynamic heating of these aircraft will, to a considerable extent, determine the structural design, demanding materials new to airframe use and requiring unconventional structural features.

The problem of survival, noted under design problems, is a very critical one demanding a considerable amount of study. Pilot protection in normal operations will be very similar to that provided for present high-altitude aircraft, although the air conditioning will demand considerably greater cooling capacity. The danger resulting from long-term exposure to high energy cosmic radiation is as yet undetermined, however, the duration of flight of these aircraft should be short enough, 10 to 40 min., that protection is not required. On the other hand, pilot escape at these extreme speeds and altitudes could require an escape vehicle comparable in complexity to the actual airplane and incorporating a power plant, stabilizing surfaces, stability augmentation, and environment control, greatly complicating the aircraft. One phase of the escape problem that will require research is the analysis of the accident potential of various portions of the performance envelope. Such analysis, combined with good design, will result in the determination of the escape system that has the greatest utility with the least impairment of the ability of the aircraft to perform its mission.

Inevitably, the configurations which satisfy the previously mentioned requirements set by aerodynamic heating and efficiency are such that the landing problem becomes aggravated. This leads to consideration of auxiliary landing jets and possibly additional landing aids such as boundary-layer control and variable geometry for higher performance research airplanes. Considerable flight research will be required in this area.

These higher performance airplanes will experience longitudinal accelerations on the order of $\pm 4g$ to $\pm 5g$ and durations of application on the order of several minutes. Although such accelerations have been experienced previously in carrier launches, the durations have been very brief. Considerable research on control configurations and pilot presentation will be required to solve the problems introduced by these long duration accelerations.

Even though many higher performance vehicles may not be intended to experience extremely low dynamic pressure or ballistic flight, special missions or emergencies may result in attaining altitudes and speeds at which reaction controls will be required. The research on the X-1B previously referred to will be extended to the new configurations.

The last item, the presentation of information to the pilot, is a critical one which is in a continuing state of change. The actual presentation to the pilot is dependent upon the mission of the airplane, and research will be necessary to determine how to provide the required piloting information. Increased complexity and automation in the piloting field appears to be inevitable.

In closing, let us take a brief look at the performance envelope in which the research airplane of the future can be expected to operate. Although at this time the controversy regarding manned airplanes versus guided missiles will be avoided, a strong feeling exists that man will always desire to go faster and higher. He will not be satisfied that an unmanned vehicle has obtained some astounding speed or distance; he will want to do it himself. The value of such performance cannot be stated at this time, however, future research may show

military, and perhaps even commercial, value in extreme performance. To illustrate the performance ranges of interest we will utilize Fig. 10 which presents the parameters of altitude and speed. In the lower left corner, the two shaded areas indicate, in general, the present performance range of service and research airplanes. We can expect service airplanes to equal the present research airplane performance in the next few years. A new research airplane, the North American X-15, is being obtained to extend flight research into the general area indicated by the label "future research types." This airplane will be used to obtain data with regard to heating, stability and control, and problems of atmospheric entry as listed on the previous figure. These data will then be available to apply to designs of hypersonic airplanes and missiles.

The chart shows an area, or corridor, labeled "boost glide aircraft" extending from the "future research types" to "satellite vehicles." Flight at altitudes above this corridor is hampered by insufficient dynamic pressure, while below the corridor the aerodynamic heating problem becomes extremely severe. These higher performance areas have many problems which will demand a large amount of research for their solution. The research airplanes will have an important role in the performance of this research and would be the logical means of performing exploration in this region.

Reviewing the research airplane program, a brief summary can be made as follows. Ten years have

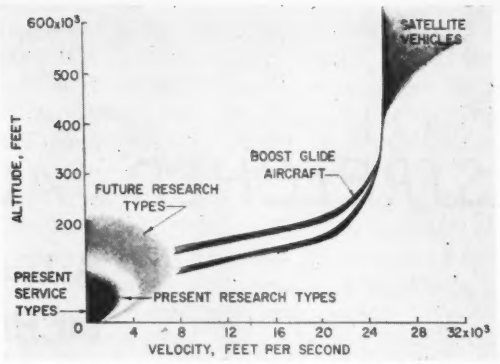


FIG. 10. Manned airplane performance regions.

brought us from speeds of about 600 miles per hour to speeds in excess of 2000 miles per hour and to altitudes above 126,000 ft. in piloted research aircraft. A great amount of flight research has been performed leading to solutions of many of the problems of flight in this speed range with direct application to service aircraft. The research airplane program is being continued by the provision, in the near future, of an airplane which we are confident will be capable of performance in excess of these present extremes. The lessons we learn from this machine and its supporting research will lead us into the flight regime of the hypersonic boost glide vehicle. The timetable for such hypersonic research vehicles is dependent upon the research effort exerted for their attainment.

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Engineering Education . . . (Continued from page 27)

[13] *Three Whys, Four Whys, and Basic Relations Between Education and the Economy*, General Electric Company, Schenectady, N.Y.

[14] *How Your Company Can Help Promote Engineering as a Career*, The Advertising Council, Inc.

[15] *After High School—What?*, Engineers Council for Professional Development.

[16] *Engineering—A Creative Profession*, Engineers Council for Professional Development.

[17] *The Giannini Film List*, Institute of the Aeronautical Sciences, New York, N.Y.

[18] *First Award Papers*, Institute of the Aeronautical Sciences Student Branch Paper Competition, IAS, New York, N.Y.

[19] *Can I Be an Engineer?* and *An Engineering Career for Your School Age Child*, General Motors Corporation, Detroit, Mich.

[20] *Career Opportunities with the Airlines*, Air Transport Association, Washington, D.C.

[21] National Merit Scholarship Corp., Evanston, Ill.

[22] *The Engineering Professions in Aviation*, 3rd Ed., 1957, Institute of the Aeronautical Sciences, New York, N.Y.

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[25] *Scholarships and Fellowships Available at Institutions of Higher Education*, U.S. Office of Education, Government Printing Office, Washington 25, D.C.

[26] *College Bound*, Board of Education of Washington County, Dept. of Guidance & Research, Hagerstown, Md., January, 1956.

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Improved shatter and craze resistance at reduced weight and simplification of edge attachment design are made possible by stretched acrylic glazing.

STRETCHED ACRYLIC

A Transparent Glazing Material for High-Speed Aircraft

John G. Stansbury
Swedlow Plastics Company

DURING AND IMMEDIATELY FOLLOWING World War II, the deficiencies of conventional acrylic sheeting, MIL-P-5425A and MIL-P-6886, as to notch sensitivity and susceptibility to crazing became apparent. Failures of enclosures in flight became more frequent as internal operating pressures increased.

Sighting dome failures on the B-29 were eliminated by changing to laminated acrylic sheeting with a polyvinyl butyral innerlayer.

The introduction of MIL-P-8184 sheeting provided a higher heat distortion material of improved craze resistance. Laminated acrylic sheeting with MIL-P-8184 faces provided a nonshattering glazing material with satisfactory service life as is witnessed by the performance of the B-47 and B-57 canopies made from this material. Despite the availability of this relatively satisfactory nonshattering glazing material, there existed, because of its weight, substantial opposition to the adoption of laminated acrylic on fighter aircraft.

The improvement in toughness possible by stretching or orienting thermoplastics was recognized many years ago, but little or no work was done on stretching acrylic sheeting. During World War II it was noticed that the thin highly stretched apexes of free blown acrylic noses had superior resistance to fracturing, but nothing was done on the subject until 1948 when Miller and Lampman[1] ran tensile tests on specimens that had been stretched uniaxially. Specimens oriented parallel to the direction of stretch were appreciably stronger than specimens tested at right angles to the direction of stretch.

Work at the Bureau of Standards for the National Advisory Committee for Aeronautics in 1952[2] showed that susceptibility of stretched acrylic sheeting to crazing by organic solvents was considerably improved over that of unstretched sheeting.

J. R. Hiltner[3, 4] reported on work done by Rohm & Haas on the development of a method to multiaxially stretch acrylic sheeting (stretching a circular section) and gave test data on the sheeting. Hiltner reported[4] that it appeared impractical for Rohm & Haas to sell stretched acrylic sheet for subsequent forming by fabricators since it appeared preferable to stretch and form the aircraft part in one operation.

In 1953, Wright Air Development Center entered into a contract (AF-33(616)-489) with Rohm & Haas to determine if biaxial stretching was equivalent to multiaxial stretching.

In discussing stretched acrylic sheeting, some explanation of the terminology that has grown up in the field is in order.

Per cent stretch is defined as $100\ (\sqrt{T_1/T_2} - 1)$, where T_1 = original thickness of sheet; and T_2 = final thickness of sheet.

This would hold true for biaxial as well as for multiaxial stretching if in biaxial stretching the per cent stretch is the same in both directions.

If the per cent stretch is different in each direction, the per cent stretch should be reported separately.

$$\text{Percentage stretch in } L \text{ dimension} = 100[(L_2/L_1) - 1]$$

$$\text{Percentage stretch in } W \text{ dimension} = 100[(W_2/W_1) - 1]$$

where L_1 = initial linear dimension in major direction of stretch; L_2 = final linear dimension in major direction of stretch; W_1 = dimension perpendicular to L_1 and T; and W_2 = dimension perpendicular to L_2 and T.

Inasmuch as "toughness" or resistance to fracturing is not adequately measured by common physical tests, it has been necessary to develop new testing methods. The Naval Research Laboratory test measures the amount of work necessary to propagate a fracture. The "K" factor resulting from this test is now accepted as a quality standard for stretched acrylic sheeting.

TOUGHNESS TESTING PROCEDURES

In 1953, J. A. Kies of the NRL reported[7] on the theory of, and a procedure for, determining the toughness of aircraft canopy materials. The toughness was expressed as dW/dA or the work consumed to propa-

Mr. Stansbury is Technical Director.

gate a unit area of controlled fracture which was made in the test specimen. The value was determined at the point of instability of the fracture—i.e., where the tensile fracture changed from slow to fast. Although this report was on unstretched acrylic sheeting, it presented for the first time a method of determining toughness of stretched acrylic sheeting. Conventional methods of determining toughness of plastic materials, such as those of Izod or Charpy, do not show the true reduction in notch sensitivity obtained by stretching.

Based on deviation outlined in reference 7:

$$dW/dA = (\pi P^2/BEt^2)Z \text{ in.lb./in.}^2$$

where

t = thickness, in.
B = width, in.
E = tensile modulus psi.
P = ultimate load, lbs.
$Z = Y(2 + Y^4)/(2 - Y^2 - Y^4)^2$
$Y = X/B$ where X = width of fracture in. at point of instability.

The original specimen used by Kies was 8 in. by 6 in. and the area between the jaws of the test machine was 6 in. by 6 in. A fracture was started in the sheeting by means of a blow with a sharp screw driver. As a means of simplifying the calculation, a graph was prepared giving the value of Z as a function of Y.

The dW/dA value includes in the formula the value of Young's Modulus, E. Since the value of E varies for different materials, and at various temperatures, it is necessary to exclude the effect of modulus in the formula in order to make true comparisons. Based on Kies' observation that the strength of a fractured material is proportionate to $\sqrt{E(dW/dA)}$, it was proposed by Convair that fracture resistance be reported as a K (for Kies) value:

$$K = \sqrt{E(dW/dA)} = \sqrt{1.57p^2Z/t^2} = 1.25(P/t)\sqrt{Z} \text{ lbs./in.}^{3/2}$$

where

t = thickness, in.
B = width, in.
P = ultimate load, lbs.
$Z = Y(2 + Y^4)/(2 - Y^2 - Y^4)^2$
$Y = X/B$ where X = width of fracture in. at point of instability.

Since the 6 in. by 8 in. specimen used a large amount of material, and since at least five specimens are necessary to assure reliable results, an effort was made to determine the minimum size specimen that would yield reproducible results. It was found that by closely standardizing the method of starting the fracture, the specimens 2 in. by 6 in. were satisfactory. This smaller size specimen and method of test have been adopted by the industry as a standard test method.[10]

Determination of fracture resistance by the methods outlined above is a destructive test, and a finished part cannot be tested without destroying the part. Since it is possible in forming stretched acrylic sheeting to damage the toughness of the material, test results on cutoffs of the stretched sheet are not a guarantee of the toughness of the formed part. However, where forming conditions are such that no substantial shrinkback would occur on an unrestrained stretched sheet, it is possible to obtain a flat test specimen of the same toughness as the formed part. This specimen is obtained by subjecting a cutoff of the sheet being formed to the same thermal cycle as is used in forming the part. Close correlation has been found between the K factor of these "flat formed" specimens and the K factor of flattened specimens obtained by cutting up a formed part.

Despite the standardization of the testing procedure, the test method is not ideal, and a nondestructive test would be most welcome. Even the reduced size specimens require a considerable amount of material. Sample preparation is exacting, and testing speed is slow (3 to 5 min. actual loading time). Further, unrestrained flat formed specimens are not valid where the forming conditions are such that an unrestrained specimen would shrink substantially (in excess of 2 per cent) in forming.

Since the birefringence of a stretched sheet can be measured nondestructively, efforts have been made to correlate K factor with birefringence.[8] The birefringence was found to be related principally to the per cent stretch, but there is sufficient correlation of birefringence with K factor to justify further work. This work will be directed toward correlating the K factor of flat formed specimens which show less correlation between K factor and per cent stretch than is found in the "as stretched" sheeting.

Development Program

Interest in stretched acrylics at the fabricator level was awakened by the work at the Bureau of Standards[2] and was furthered by the reports of Rohm & Haas on this same subject.[3, 4] Because of our firm belief in the future possibilities of the material, we have carried out our development program on stretched acrylics for aircraft enclosures at our own expense.

Our initial approach was stretch forming a part to the required percentage stretch to give optimum toughness. Although this method presented the ultimate in mechanical simplicity, since it was nothing other than a modification of the vacuum-pot technique, it had one serious drawback for large-scale production. A normal pot stretch has a material yield of approximately 15 per cent. This is based on a less than 25 per cent utilization (at 100 per cent stretch) of the material within the hold-down area. Although it might be possible by choice of process and equipment to improve the yield of material in the part, a yield of 50 per cent would be excellent on most parts, while a 20 per cent yield would not be unexpected in others. While the use of such a procedure might be justified for making experi-

mental parts, we felt that it would be inadvisable initially to develop a process which was basically uneconomic, insofar as material yield is concerned, for large-scale production.

The next approach was to mechanically stretch acrylic sheet in one direction and then form the sheet while still hot, in such a manner as to induce stretch at 90° to the original direction of mechanical stretch. For this purpose, we made tools to form a half scale F84F canopy. Parts produced did not have the expected toughness. Close control of temperature and rate of draw was not maintained. At the time we performed this work, we were still ignorant of the significance of these controls on the ultimate toughness of the finished part.

The reported success of Rohm & Haas in multiaxially stretching flat sheet to give good quality material of the required toughness, together with a belief that biaxial stretching of flat sheet was equally practical, suggested another approach, that of postforming prestretched material.

An attempt was made to reheat at 300°F. multiaxially stretched sheeting restrained in a frame to prevent shrinkage. The heated sheet was to be formed by either contact or differential pressure techniques while still restrained in the frame. Frame development represented a problem, and a clamping device, similar to the "Kindelberger" jaws used in stretch forming of metal, was regarded as necessary for the forming of canopies. The procedure was dropped because of the high loss of sheets which occurred by tearing during the reheating process.

The next approach in forming flat-stretched sheet was based on the belief that this sheeting might be formed at temperatures below that at which substantial shrinkage took place. Considerable experimental work was done in developing the most desirable forming temperature for both stretched MIL-P-5425A and stretched MIL-P-8184 sheeting. In this work, we developed the relationship of shrinkage to heating temperature. With stretched MIL-P-5425A, the curve was fairly flat out to 185°F.; between 185°F. and 215°F., it increased markedly in slope, while between 215°F. and 230°F. it was almost vertical.

The curve for stretched MIL-P-8184 sheeting was similar in shape, but the temperature at which a marked shrinkage occurred was somewhat higher. This curve was substantially horizontal to 215°F. It increased in slope from 215°F. to 230°F., and at 230°F. it dropped off sharply. At 250°F. the stretched sheeting had almost returned to its original unstretched condition.

To check out our theories as to effect of warm forming on toughness, we formed specimens with a substantial compound contour, the size of the Naval Research specimens, and had tests run for comparison of "as stretched" and "formed" toughness.

The results of these tests which are given in Table 1 showed a substantial increase in dW/dA value for the formed specimens.

TABLE 1

Base Sheeting	% Stretch	Type Stretch	Condition	dW/dA
MIL-P-8184	81–84	Multiaxial	As stretched	21.6
MIL-P-8184	81–84	Multiaxial	Postformed with compound contour	42.0

The validity of tests on compound contoured specimens run in flat jaws was questioned by the NRL. Examination of the compound contoured specimens showed that the break was not normal to the surface of the sheet, so the area of fracture determined from thickness of the sheet which was used in the dW/dA calculation was obviously incorrect.

Subsequent work on testing nonflat specimens indicated that while the initial compound contoured specimens gave high results, it was also possible to have nonflat specimens with other contours which will give low values.

To overcome the difficulty experienced in testing compound contours in flat jaws, a simple contour $7^1/_2$-in. radius standard specimen was devised and curved jaws were built to test it. It was felt that results of tests on a cylindrical section pulled parallel to the axis of the cylinder in curved jaws would be comparable to results run on flat specimens. As an added check, tests were run on flat specimens which had been heated at the same temperature and for the same time as that used for forming the cylindrical sections.

The results of these tests, given in Table 2, indicated that stretched MIL-P-5425A and stretched MIL-P-8184 could be formed under the condition which we had established with but slight decrease in toughness.

These tests also indicated that toughness on flat specimens heated through the same thermal cycle that is used in forming a part are indicative of the toughness of the part. This has been proven by extensive comparisons of the toughness of a flat-formed specimen and specimens cut from a flattened part.

Based on successful postforming of flat-stretched sheet, a machine was constructed to stretch or produce stretched sheeting with a finished size of 48 in. by 48 in. It was felt that this size sheet would be large enough for all aircraft windshields and for windows for all commercial aircraft. It was further believed that the manufacture of stretched sheets 48 in. by 48 in. would

TABLE 2

Base Sheeting	% Stretch	Type Stretch	Condition	dW/dA
MIL-P-5425A	104	Biaxial	As stretched	16.1
MIL-P-5425A	104	Biaxial	Cylindrical section	15.0
MIL-P-5425A	104	Biaxial	Flat specimen heated	16.0
MIL-P-8184	82–85	Multiaxial	As stretched	20.9
MIL-P-8184	82–85	Multiaxial	Cylindrical section	18.0
MIL-P-8184	82–85	Multiaxial	Flat specimen heated	17.8

indicate the problems that might arise in stretching larger sheeting which would be necessary for the production of aircraft canopies.

At the time that this machine was under construction, we entered into a development program with Convair, San Diego[9] on plastic glazing for the F-102 canopy. This canopy was initially made from 1/2-in. monolithic MIL-P-8184 sheeting. With the immediate availability of stretched sheeting, Convair began an intensive program on adapting the canopy design to stretched MIL-P-8184 sheeting. It was found that the 1/2-in. monolithic sheeting could be replaced with 0.350-in. stretched sheeting with a substantial saving in weight and a vast increase in safety with regard to the hazards of explosive decompression. The lack of notch sensitivity of stretched sheeting made it possible to simplify the edge design by drilling through the body of the enclosure.

In this program, a large amount of data was determined on the properties of stretched MIL-P-8184 sheeting. The method of testing for fracture resistance was standardized. Based on preliminary data, it was decided to set a minimum of 2,500 at 75° ± 2°F. for the *K* factor of the stretched part, although the lower limit at which nonshattering properties might be expected never was actually determined.

Fig. 1 illustrates a comparison of the resistance to fracture propagation between "as cast" MIL-P-8184 parts and parts made from stretched MIL-P-8184 sheeting. Both panels were shot with a 30-cal. rifle with the panels in a F-102 canopy frame, under a pressure load of approximately 6.5 psi. The full merit of the resistance to fracture propagation of stretched material over as cast material is evidenced in the photograph. The as cast panel was made from 1/2-in. thick material which literally blew to pieces. The stretched material, which was 0.350-in. caliper, suffered only a small hole.

Operation of the small stretching machine established that toughness of the stretched sheet is dependent upon the amount of work actually put into the sheet in stretching. Because of the wide variations of stretching conditions possible, we believe that customer requirements should specify only the minimum *K* factor required and not the per cent stretch.

The Convair program also covered the evaluation of plastic material with improved high-temperature properties. Polymethyl alpha chloracrylate sheeting was a promising candidate. Although the stretching temperature was very close to the decomposition of the material, a technique was developed for producing stretched PMACA. Since the material available did not have a surface satisfactory for use in aircraft enclosures, we developed a refinishing technique which produced a sheet with excellent optics.

To take advantage of the high-temperature characteristics of PMACA, it was necessary to develop laminates and adhesives with satisfactory properties at 240°F. Although fiberglass laminates exhibited superior high-temperature properties, combinations of

FIG. 1. Gunfire comparison of as cast vs. stretched F-102 panels.

PMACA and fiberglass laminates showed substantial warpage when tested over the temperature range of −65° to +240°F.

Synthetic fiber (nylon) epoxy bonded laminates were promising as edge attachments for PMACA. Edge-attachment specimens of PMACA with these laminates had strengths of 750 to 1,000 lbs. per in. of width at 240°F., when tested according to ASTM 638–48T. Failure most frequently occurred in the adhesive line.

Although we were able to successfully produce a stretched PMACA enclosure for the F-106, work was stopped when it was decided that the material would not be produced commercially.

Electrically Heated Transparent Panels

As a part of the Convair development program, work was started on a stretched acrylic panel which would have an electrically conductive coating for heating the panel for defogging. The end result of the program[9] was the production of a flat laminate which was subsequently formed to panel configuration. The laminate consists of a 0.350-in. stretched MIL-P-8184 sheet, a 0.075-in. layer of polyvinyl butyral and a 0.060-in. to 0.125-in. face sheet of Sierracin 611 which carries the conductive coating. The coating is against the vinyl innerlayer. The thin-face sheet which is to the inside of the airplane, is nonstructural and "floats" on the 0.350-in. structural member.

The problems involved in developing a conductive coating which would withstand laminating and forming have been largely solved. The optical properties of the formed part are satisfactory when used as a side enclosure, but before the material can be used for windshields, further improvement in optics is probably necessary. The panel in its present state of development has a light transmission of over 65 per cent. It is capable of continuous operation at 1 watt per sq.in., and is proof tested before delivery to the customer at 2 watts per sq.in. for 10 sec.

The panel has a gradient conductive coating so that the temperature is uniform throughout the entire part.

XUM

FIG. 2. Stretched F-101B windshield side panel as viewed from the pilot's position.

The temperature is controlled by a sensing element in the panel to operate on a power on-off basis at a temperature of 100°F. to 110°F.

PRODUCTION PROGRAM

A larger machine capable of stretching sheets up to 90 in. by 90 in. in size has been built, and is in operation. Over 1,250 panels (625 ship sets) have been produced for the F-102 as well as a substantial number of enclosures for the TF-102 and F-106. All parts delivered have been of satisfactory optical quality, and with the exception of a few parts at the beginning of the program, all parts had a K factor of above the minimum 2,500 initially chosen.

F-102 panels went into service in January, 1956. There have been no service failures, and only two parts have been replaced, both for mechanical damage.

Shortly after the beginning of commercial production, it was found that a substantial portion of the thick MIL-P-8184 sheet purchased for stretching had optical defects which enlarged in stretching and resulted in an optically unsatisfactory stretched sheet.

We have found it possible to optically grind and polish this sheeting using the techniques which were developed for refinishing PMACA sheeting. With the improvement in quality that has been available due to this polishing procedure, more and more customers are demanding optical perfection and an increasingly large percentage of stretched sheets are being polished before forming.

When production of canopies with a substantial amount of draw was begun, it was found that forming pressures were so high that mark-off from the die occurred on the formed part. To overcome this difficulty, we have developed a free forming technique for stretched acrylic sheeting.

Fig. 2 is a photograph of a grid board through a production F-101B windshield taken from the pilot's eye position. This windshield was formed from ground and polished sheeting by a free forming technique. Since the forward section of this windshield is being viewed at an angle of approximately 20° to the glass (70° off perpendicular), the optical properties of this part are remarkably good.

We have produced approximately 100 ship sets of windshields and canopies for the F-101B, as well as a number of windshields and canopies for the F-105. We have likewise produced a substantial number of Lockheed Electra and the Boeing 707 windows, as well as furnishing stretched sheets for the DC-8 windows.

We expect a continuation of volume production in stretched acrylic parts since the commercial aircraft programs mentioned above are just beginning, and the Armed Services are demanding stretched acrylic enclosures on new aircraft, as well as weighing the merits of retrofit on certain current programs.

FUTURE DEVELOPMENT WORK

As might be expected, continuous development is under way on techniques for improving yield and quality of stretched sheeting and formed parts. Work is actively under way on a method for flat forming test specimens so that they will give toughness results comparable to the results obtained on parts made by the free forming technique. Efforts are being continued on correlating nondestructive methods of determining toughness with the tensile fracture method currently being used.

Since polymethyl alpha chloracrylate will not be commercially available, we are continuing our search for sheeting for stretching which would have improved high-temperature properties. Both high softening linear polymers and polymers which are capable of being cross linked to high heat distortion after being stretched are being investigated.*

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(*Continued on page 56*)

* The writer wishes to acknowledge the help of M. E. Latham and W. Yamaguchi of Swedlow Plastics Company in preparing this paper. J. R. Hiltner, John Woodman and Orville Pierson of Rohm & Haas; W. R. Lee, E. Schiff and W. E. Olds of Convair, San Diego; J. E. Kies and M. J. Kramer of NRL, all cooperated in the development and standardization of test procedures. The help of WADC which sponsored Contract No. AF 33(616)-489 on Biaxially Stretched Plastic with Rohm & Haas is greatly appreciated. WADC has prepared a tentative specification (MIL-P-25690) for stretched acrylic sheets and parts, which is currently being circulated for comment.

The development of conductive coatings and means of laminating these coatings to stretched acrylic sheeting was the work of Libbey-Owens-Ford Glass Company, and the Sierracin Corporation of Burbank, Calif.

Turbine engines, both jet and turboprop, can be operated successfully in water-based service aircraft.

Why should we worry about salt atmosphere environment?
What does salt do in an engine?
How can its harmful effects be minimized?

The Turbine Engine in Salt Atmosphere Operation

F. Herbert Sharp
Convair, A Division of General Dynamics Corporation

THE CONVAIR R3Y Tradewind (see Fig. 1) is powered by four Allison T-40 turboprop engines. Eleven airplanes have been delivered to the Navy and are in squadron services with VR-2 at Alameda.

The Convair XF2Y-1 Sea Darts (Fig. 2) are part of a hydrodynamic research program to investigate water-basing of supersonic aircraft. Many types of skis have been tested over a 4-year period. Operation and maintenance of the original J34 jet engines and later the J46 engines in this rather damp environment form the background for the balance of our discussion here.

The R3Y and the Sea Dart figures were selected to show some of the wetter operations during the test program. However, any sea condition which approaches the formation of white caps will pretty well fill the air for several feet above the surface with a salty mist. This is the ambient air in which the seaplane operates during its water-borne life. The turbine engines consume huge quantities of this air. Some of the salt fails to go on through the engine, preferring to stay inside and give us some interesting problems.

The Intruder

Salt remaining in the engine has three effects of primary concern:

(1) Deposits on compressor blades and stator vanes.
(2) Physical interference.
(3) Corrosion (see Fig. 3).

Deposits of salt on the compressor rotor blades cause a loss of pumping efficiency. Because each blade is a carefully designed airfoil, any surface irregularity is detrimental. In the early stages, this simply results in a reduction of power and an increase in s.f.c. and turbine-in temperature. These losses increase as the deposits build up until the blade stalls, very much as a wing does when ice forms on it. This condition usually makes itself evident when the pilot advances the throttle sharply. The resulting compressor stall is very noisy and brings about an almost complete loss of power.

The author is Senior Project Engineer.

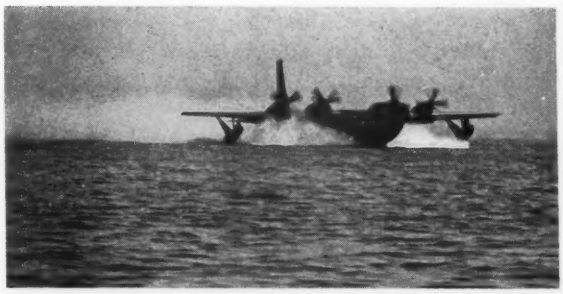

FIG. 1. Note random spray drawn up and forced into engine air inlet.

FIG. 2.

Physical interference has been experienced in two forms. The first is an actual binding together of the rotating and stationary parts in the compressor section. This is an unusual case and occurs only under certain extreme conditions. Early in the hydrodynamic test program of the XP5Y seaplane, a day of testing involved extensive use of reverse thrust on high-speed taxi runs. Unusual amounts of spray were pumped through the engines. On preflight inspection the next morning, none of the eight power sections could be rotated by hand. The very close running clearances between compressor blade tips and compressor case, as well as

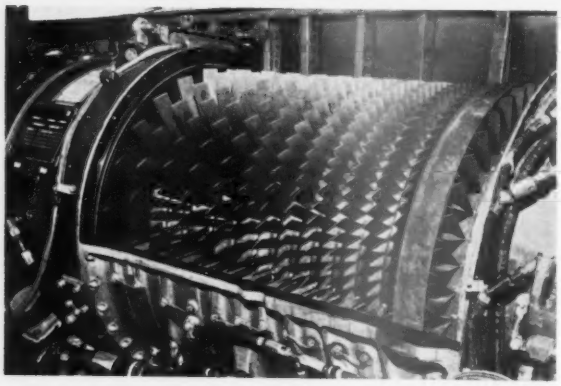

FIG. 3.

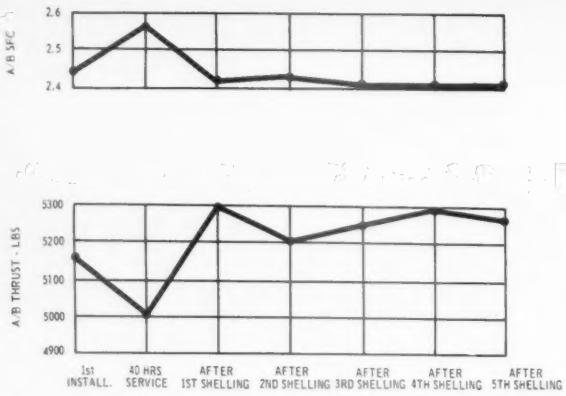

FIG. 6. Thrust and s.f.c. change with walnut shelling on J46-WE12B engines.

FIG. 4.

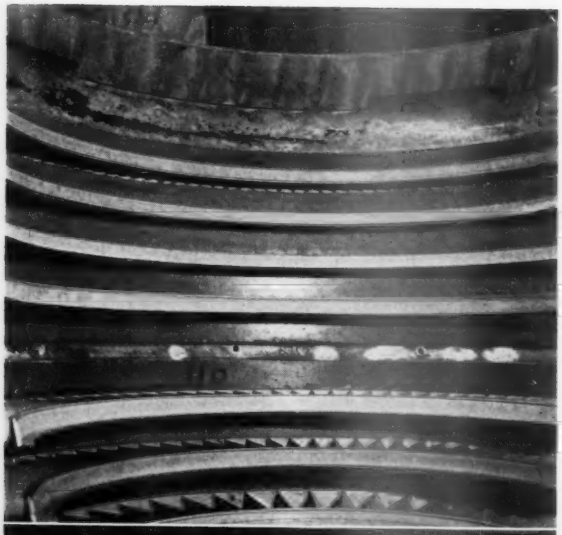

FIG. 5.

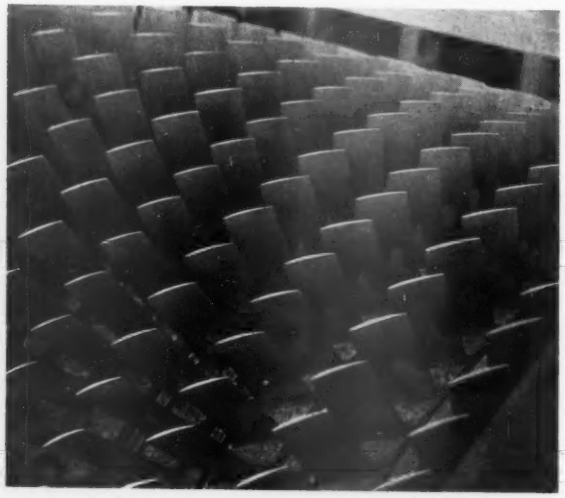

FIG. 7. Hard blade deposits before walnut shelling.

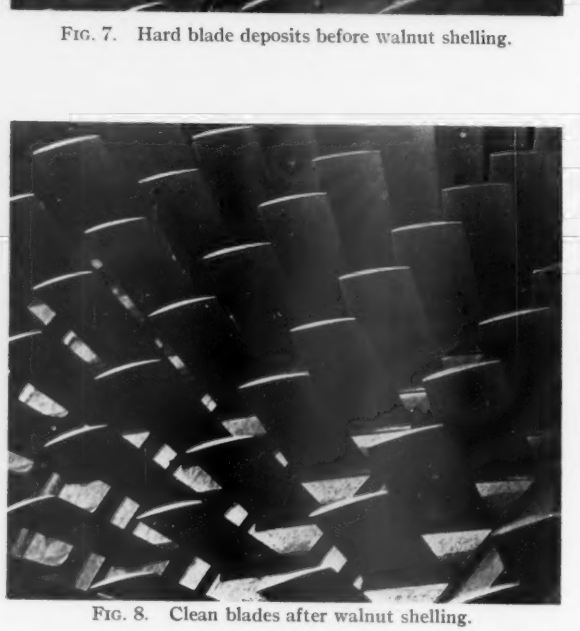

FIG. 8. Clean blades after walnut shelling.

between stator rings and compressor hub, had been bridged by residual salt deposits. Steam cleaning the idling engine on the beach prevents this accumulation.

A more common type of interference is caused by the expansive force of salt, which collects underneath the stator rings where they are embedded in the compressor case. This forces the stator rings radially inward and causes them to rub on the compressor hub. This rubbing can progress to the point of binding and cause the compressor rotor to actually tear out the stator rings. Localization of this corrosion is fostered by the steel stator rings being mounted in grooves in the magnesium compressor case (see Figs. 4 and 5).

Corrosion effects within the engine are less spectacular but require just as much attention. Pitting of the blades progresses at a slow rate and is of minor concern. However, interior surfaces of the magnesium compressor case undergo severe corrosion unless properly protected and maintained. The severe pitting is accelerated by the proximity of steel stator rings. This corrosion can soon render the case structurally useless if allowed to progress.

Corrosion and malfunction due to moisture on the engine's external parts, electrical components, and accessories must also be accounted for. They are not highlighted here since their prevention is part of the seaplane designer's normal task and the procedures are well known.

Answers

The basic design of the airplane must hold ingestion of heavy spray and solid water to a practical minimum. This can be done to a surprising degree by proper design of hull bottom, bow shape, hull spray dams, and a favorable location of the engine air-inlet ducts. In some cases, alternate air inlets are required during certain operating conditions.

Ambient spray will always be drawn through the engine since this is its operating environment, but heavy spray and green water can be eliminated.

All internal parts of the engine must be of materials as close together in the electrolitic series as is practical. Steel stator rings imbedded in a magnesium compressor case, plus salt atmosphere, form an ideal battery resulting in "un-ideal" corrosion. Compatible materials are relatively free from corrosion when properly maintained.

A protective surface treatment which would slow down corrosion inside the engine was desired. Many materials were tested. A special finish called "Nubelon S," by the Glidden Paint Co., gave excellent results. This finish was applied to the compressor cases (inside and out) at North Island Naval Air Station and to the rotor and stator assemblies of two engines during overhaul. The material is sprayed on and the parts are cured in an oven at about 225°F. The result is a very hard and extremely smooth surface of less than 1 mil thickness. The glassy smooth surface also reduces the build-up of deposits on the compressor blades. All engines were later given the Nubelon S treatment in the contractor's plant.

Steam cleaning the J46-WE12B engines after taxi operations was not removing the hard build-up of foreign material on compressor blades. A procedure for cleaning these blades by injecting ground walnut shells in the operating engine during ground runs was developed and successfully used during the program.

To determine the most effective r.p.m. range and amount of walnut shells, one engine with the following history was put through a carefully controlled test:

13.63 hours—Installed in aircraft.

27.62 hours—Removed from aircraft due to stall condition when attempting to go from military power to afterburning (14 hours in aircraft).

30.56 hours—Walnut shelled on test stand.

40.82 hours—Installed in aircraft.

49.19 hours—Walnut shelled in aircraft.

53.71 hours—Removed from aircraft (13 hours in aircraft) due to compressor stall when attempting to go from military power to afterburning. Time on engine prompted removal rather than walnut shelling in the aircraft.

Method of Test

(1) Mount engine on test stand with intake duct installed.

(2) Remove compressor case (upper half only) and photograph typical blade. (Typical blade is on tenth stage and has a bevel mark on outboard-aft edge).

(3) Install compressor case, remove and plug pressure lines at Micro-Jet, remove and plug bleed outlet on compressor.

(4) Start engine and allow to idle for 5 min. Inject 5 gal. of .020 size walnut shells into inlet duct allowing free fall through 1-in. I.D. hose while r.p.m. is fluctuated between idle and 6,500 r.p.m.

(5) Check fuel flow and thrust for power settings of idle, 100 per cent r.p.m., military, and afterburning.

(6) Remove compressor case and photograph typical blade with camera at same place as initial photograph was taken.

(7) Install compressor case and repeat items 4, 5, 6, for r.p.m. ranges of 6,500 to 8,500.

(8) Install compressor case and repeat items 4, 5, 6, for r.p.m. ranges of 8,500 to 10,000.

(9) Determine from observation and photographs of the typical compressor blade which r.p.m. range is most effective in corrosion removal. Using this r.p.m. setting (1,500 r.p.m.), inject 12 gal. of walnut shells in 3 gal. increments per items 4, 5, 6.

(10) Compare initial, progressive, and final data on fuel consumption and thrust to determine efficiency gain.

Fig. 6 shows the engine performance at time of installation, the deterioration during 40 hours of service, the tremendous comeback during the first walnut shell-

(*Continued on page 56*)

The two-gyro stable platform—the transition between present airborne reference systems and the needs of the future.

A New Stable Platform for Today's Aircraft *TODAY*

J. F. Schoeppel
Lear, Incorporated

WE HAVE ALL BEEN READING and dreaming of the aircraft of the future—a sleek, multi-Mach jet—automatically flown and automatically navigated by means of complex gyro references and central computers. The pilot of this fancied aircraft would be an airways "king" with all his menial tasks performed automatically and his major concern his military mission or the comfort of his passengers.

Looking inside this machine, we find that, instead of the usual seven to ten reference gyros found in today's aircraft, a master stable platform of subminiature dimensions and unheard-of performance has been substituted.

The central master stable platform has been idealized as a multiple (usually three) gyro instrument approximately 6 by 6 by 6 in. weighing approximately 8 lbs. Free drift rates of 0.01° per hour would assure verticality under any condition of flight (including rough air and high-speed turns) of better than 0.1°. Adequate output signals without servo repeaters for up to ten remote indicators or control systems would be provided. The idealized stable platform could be bought for about $2,500 in aircraft quantities. Service life is suggested at 10,000 hours without attention of any sort.

In order to utilize the ability of military aircraft to fly in all attitudes or civil VTOL passenger aircraft to accomplish a vertical take-off, a truly all-attitude gyro reference would be required. The idealized master stable platform thus must present without ambiguity an exact three dimensional "picture" of the attitude and heading of the aircraft in the form of electrical signals. A central attitude display operating with reference to these signals would show the pilot his attitude at all times. The aircraft's automatic pilot would cause it to be flown along selected courses and in selected flight paths based on the reference signals from the master stable platform.

The fact remains that when a serious attempt is made by an aircraft manufacturer or government agency to procure such a stable platform for an airframe in planning, it simply cannot be obtained from any instrument manufacturer. All manufacturers are working hard toward such a goal, but in terms of a platform available for aircraft being engineered today, such a goal is not attainable with the use of today's techniques and methods.

Let us examine, item by item, the instrument problems remaining which obstruct development of an idealized master stable platform. By far the most imposing is the development of a truly miniature gyro element for a stable platform with a day-in, day-out free drift rate of 0.01° per hour. In a complete all-attitude stable platform of 6 by 6 by 6 in.—an equivalent volume of 216 cu. in.—the largest gyro wheels possible in a three-gyro platform of conventional type would have an angular momentum of not more than 0.1 million gm.cm.^{2} per sec. With ball-bearing precession axis suspensions, one would expect 0.1 million wheels to produce free drift rates of 30° per hour. Such drifts are more than three orders of magnitude greater than desired in our idealized platform.

Probably the finest technique available today for producing very low platform drift rates with minimum size wheels is precession axis flotation. With this technique, the gyro rotor and its driving stator are enclosed in a carefully designed float which nominally removes all weight from the gyro's precession axis bearings. In this configuration, jewel bearings are generally used with very small tungsten carbide trunnions. It has been our experience that improvements of 30 to 60 times are possible when the flotation technique is employed as compared to drift rates of the older ball-bearing suspended gyro elements. Applying a 30 to 60 times factor to 30° per hour, we can predict with present-day techniques free drifts of 0.5° to 1.0° per hour using a floated wheel of 0.1 million angular momentum.

It should be pointed out that many organizations, both industrial and educational, have demonstrated free drifts well below these figures with comparable gyro wheels. However, it is becoming increasingly apparent that such demonstrations are similar to special speed and mileage runs on automobiles. Most such record figures are obtained under carefully controlled laboratory conditions using a gyro which has been carefully trimmed up for the run. Special test stands and test techniques

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are used which serve to eliminate many important causes of gyro drift from the test. Gyro users prefer the considerably higher drift figures obtained in day-in, day-out testing under a wide variety of temperatures and vibration, with the gyro element tested *in six positions with respect to gravity*. Under rigorous test conditions such as these, drifts of 0.5° to 1.0° per hour in this size gyro are the best obtainable at this time.

Chances for improvement of present floated techniques are good. The primary obstacles are time and the financial support necessary to perform the intensive research required. It should be noted that at a random drift level of 0.01° per hour, with a 0.1 million angular momentum gyro, torques of 0.04 dyne cm. form the uncertainty level. Refinements in rotor bearings, rotor structures and materials, float structures and materials, and advanced bearing techniques all must be enormously improved in order to reduce drift rates to this low level.

The idealized master stable platform suffers from a second major problem in terms of today's techniques. Even a platform with free drift rates on all axes better than 0.01° per hour will not necessarily maintain verticality under all conditions of flight within 0.1°. *Low free drift alone does not necessarily insure verticality*, although low free drifts are generally important in securing a high degree of verticality.

With the ideal stable platform we must provide a Schuler-type erection system with certain computed compensations. While the conventional Schuler-type erection system is theoretically insensitive to aircraft accelerations, it is difficult to utilize it with the ideal parameters taken from system theory. The basis of Schuler-type erection is a normally undamped 84-min. pendulum, otherwise known as an earth's radius pendulum. It is of little use in practical aircraft without a fast non-Schuler initial erection cycle because of the inherent oscillatory nature of the Schuler system. A series of compensations and computed corrections is currently in vogue as a means of producing a platform erection system of the Schuler type with minimum sensitivity to aircraft accelerations and with reasonable initial settling time.

The state of the art of platform erection systems, in our opinion, has not yet reached an all-flight-condition verticality of 0.1° in miniature systems.

A third problem, that of providing direct coupled multiple outputs from a miniature platform, at first glance seems simple. Actually, it is not possible to load *miniature* output synchros with more than one or two high impedance control transformers without loss of platform accuracy. Another problem is the lack of standardization of synchro output parameters between manufacturers of aircraft systems and instruments which further hampers the use of a single reference.

A fourth problem, somewhat more subtle but certainly most important in establishing feasibility of a master reference, is the present high cost and complexity of stable platforms. It is believed that this condition is one engendered by newness of the equipment rather than by inherent limitations of the concept. Many indications are at hand which show that costs of stable platforms can be brought down as engineering maturity is reached and new production equipment and processes become available.

Service life of 10,000 hours without attention is a goal which will not be easily reached. The present state of the art of high-performance gyro instruments is on the order of 2,000 hours. True hermetic sealing of gyro instruments has been a great step in bringing service life to this point. At first glance it appears that the jump from 2,000 to 10,000 hours is merely one of engineering advancement in the fields of ball-bearing materials, lubricants, retainer structures and materials, etc. However, it is rapidly becoming apparent that to reduce mass shifts of high speed gyro wheels to the point where drift rates of 0.01° per hour are possible, it is necessary to increase rotor-bearing preloads substantially. The highly preloaded rotor bearings, in turn, wear out very rapidly and, thus, greatly reduce service life. The increased wear drastically affects platform drift. At the moment there is no answer to this paradox except further investigation of better wearing bearing materials and application of higher and higher tolerance ball-bearing manufacturing techniques in order to reduce the requirement for such heavy preloads.

Some engineering solutions to individual problems defined in the past few paragraphs are presently available, provided each problem is considered singly. In the development of the master stable platform described previously, most unique methods of improvement of a specific characteristic cannot be used because they simultaneously deteriorate other important characteristics. A good example is the paradoxical situation of low drift and long service life requirements. Tight adjustment of the gyro rotor-bearing preload allows minimum free drift rates but causes very short service life. Adjustment of the gyro rotor bearing to a light preload allows many thousand hours of unattended service but seriously deteriorates platform free drift. It is the development of new solutions to each individual problem which do not deteriorate other significant characteristics that forms the challenge to today's stable-platform engineers.

If our idealized platforms are still somewhat in the future, what are our military and commercial aircraft to fly by in the meantime? At first glance, the choice might be early stable platforms developed in the search for a miniature, all-attitude low-drift master reference. Several satisfactory platforms of this type, using ball-bearing precession axis suspensions, have been built and tested. These units can be utilized as master references for new aircraft presently under development, despite their rather large size and weight and their very considerable unit cost.

However, another instrument is available with certain unusual features which make it equally or more attractive than the conventional three-gyro platforms now available. This is the two-gyro, all-attitude, mas-

ter reference—the transition link between conventional aircraft gyros and precision miniature stable platforms. It is a hybrid type of gyroscopic instrument of small size, minimum weight, and minimum complexity. The considerable difference in complexity between this instrument and presently available three-gyro stable platforms makes it much less expensive and considerably more reliable in day-in, day-out operation.

The two-gyro master reference combines accuracies of the best vertical gyros now under development with the stabilized azimuth feature of the conventional three-gyro stable platform and the nontumbling features of the most complex all-attitude stable platform. It is an "asymmetrical" instrument in that drifts of the directional gyro element are much lower than drifts of the vertical elements. The asymmetry corresponds to a like difference in drift requirements found in operation of most aircraft. Operation of the aircraft directional reference without magnetic slaving has pushed requirements for directional elements to approximately one order of magnitude lower drift than the vertical elements.

Its very strong resemblance to conventional gyro structures and techniques and, particularly, to structures and techniques already widely tested in service and in the laboratory make it a sound and sure element of great reliability. A broad test program has shown life of all elements to exceed 2,000 hours *without passing outside the original drift specifications.* Repair costs are quite low and cost of parts replacement is very low.

A most important feature of this unusual new instrument is its capability of providing directly from its multiple synchro or resolver outputs data necessary for all-attitude flight, including planned Immelmann or Cuban Eight type maneuvers and sustained vertical flight. Probably the most overlooked instrumentation problem of new military aircraft currently nearing production is their ability to fly in any attitude, including the vertical mode, nearly as easily as in level flight. It is little realized that the pilot of an all-attitude high-performance military aircraft will not be capable of executing his mission unless new gyro references are incorporated in the weapons system. The all-attitude requirements of these aircraft *require* the use of an all-attitude gyro reference, such as the two-gyro master reference.

The two-gyro master reference is designed to provide synchro displacement signals as basic reference inputs to all-attitude flight instrument presentations and, simultaneously, to high-performance automatic pilots. The reference output synchros can also be employed at the same time as a basic attitude reference for fire control systems, navigation systems, and other instrument presentations and controls.

A second important function of the two-gyro master reference is its ability to provide stable azimuth signals without intercardinal tilt error. This error, somewhat similar to the velocity error in a universal joint, is due to the inability of a gyro gimbal system to accurately indicate azimuth when the normally vertical outer axis of a directional gyro is displaced from vertical in a banked turn. When the gyro spin axis is on a N-S heading, the maximum errors will be found when the gyro gimbal axes are at 45° to the gyro spin axis. In the two-gyro master reference, the high-accuracy directional gyro is stabilized in both roll and pitch accurately and continuously by the vertical gyro element. Thus, its output at all times is azimuth no matter what acrobatic maneuvers the aircraft performs. Pilots flying high-performance aircraft in vertical flight will be particularly pleased that discontinuous reactions of the azimuth scale due to gyro gimbal lock have also been eliminated. The aircraft azimuth is indicated exactly from the stabilized directional gyro and is not subject to gyro gimbal vagaries.

It should be noted that certain classified military maneuvers requiring controlled acrobatics make it impossible to provide accurate azimuth indication from conventional directional gyros without intercardinal tilt errors. The two-gyro master reference eliminates this problem and makes it quite practical to perform any or all of these maneuvers without upsetting the accurate azimuth indication.

The two-gyro master flight reference possesses several other important features which are summarized below:

(1) It is a small physical package, with dimensions of 6.3 by 6.2 by 13.3 in., or approximately 520 cu.in. in volume. The packages of other system components are likewise of miniature size. Fig. 1 illustrates a conventional arrangement of components, and lists weight and size data for a typical two-gyro all-attitude, master reference system.

(2) Weight of the basic two-gyro package illustrated in Figs. 1 and 2 is approximately 17 lbs.

(3) Owing to new instrument design techniques, the production price of the two-gyro master reference is expected to be approximately half that of currently

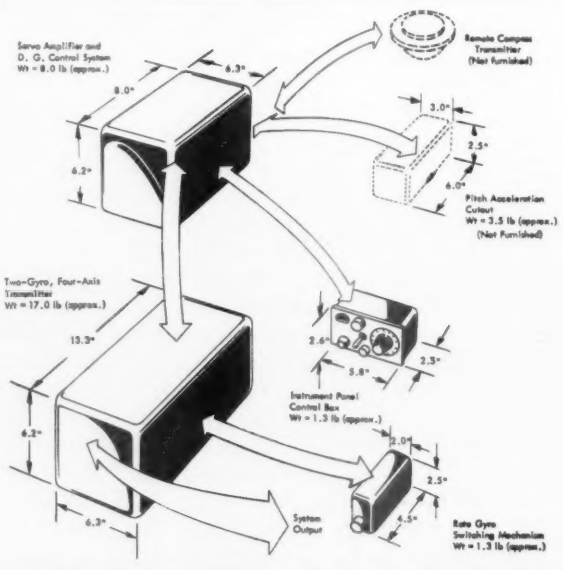
Servo Amplifier and D. G. Control System Wt = 8.0 lb (approx.)
Remote Compass Transmitter (Not Furnished)
Pitch Acceleration Cutout Wt = 3.5 lb (approx.) (Not Furnished)
Two-Gyro, Four-Axis Transmitter Wt = 17.0 lb (approx.)
Instrument Panel Control Box Wt = 1.3 lb (approx.)
System Output
Rate Gyro Switching Mechanism Wt = 1.3 lb (approx.)

FIG. 1. Two-gyro, four-axis, all-altitude control system.

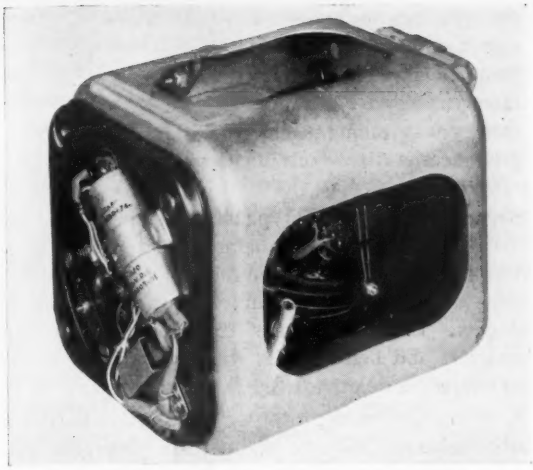

FIG. 2. Steel vertical gyro used as prototype for two-gyro reference vertical element.

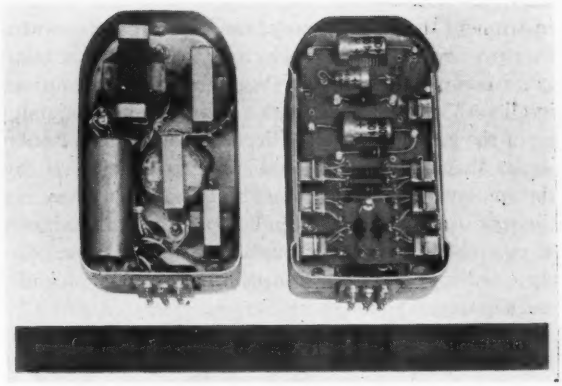

FIG. 7. Transistor amplifier for integral amplification.

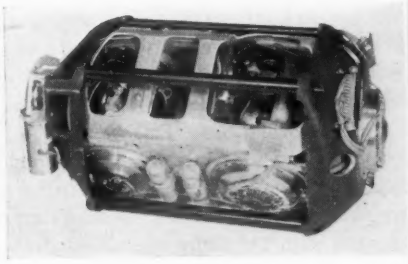

FIG. 3. Two-gyro master reference with hermetic enclosure removed.

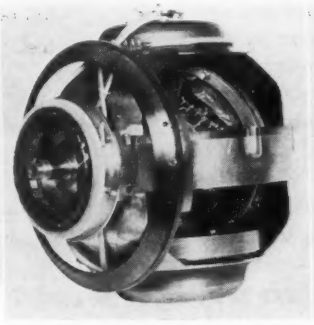

FIG. 4. Directional gyro element ready for mounting in outer roll gimbal.

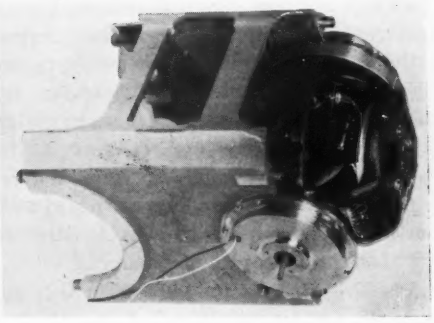

FIG. 5. Mounted vertical gyro element.

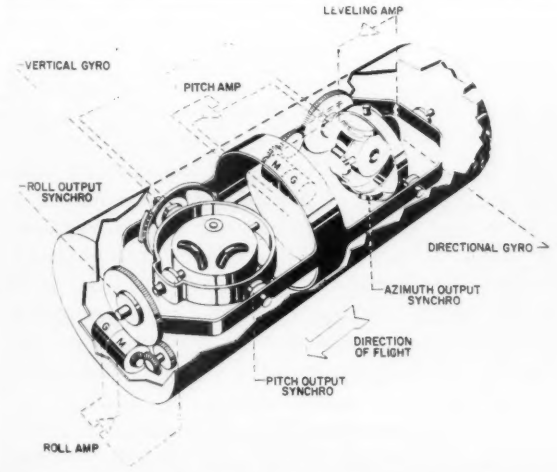

FIG. 6. Gimbal arrangement—two-gyro master reference.

FIG. 8. Compass controller, Lear Model 3804A.

available three-gyro platform references of greater complexity when compared on the basis of the same length production runs.

(4) A maximum of simplicity is realized in the new instrument through the use of *two* high-angular-momentum gyro rotors suspended in a gimbal system of minimum complexity—this arrangement allowing motions in all axes without tumbling of either gyro. An analysis of the geometry of all-attitude gyro instrumentation shows that all necessary stability can be achieved by the employment of two gyro wheels. In other respects the new instrument has been designed with a minimum of components, such as amplifiers, gimbal axes, synchro sensing elements, torquers, alignment pickoffs, and slip rings.

(5) New high levels of performance of both the vertical- and directional-gyro elements are achieved by the use of steel gimbal structures on the support of all sensitive axes of the new instrument. These techniques, which have been so successful in conventional vertical and directional gyros, prove unusually well-suited to the two-gyro master flight reference.

(6) All important features of present or proposed Air Force or Navy slaved directional gyro systems can be included in the two-gyro master reference system without penalty. The basic two-gyro master reference can be integrated with navigation systems built to Air Force J-4 or Navy MA-1 or more advanced specifications.

(7) Performance of the directional gyro with slaving removed has been laboratory tested at 2° per hour. Further refinements of the directional gyro will yield a final performance of 1° per hour.

(8) Free drift of the vertical gyro is 10° per hour, both at room temperature and at −65°F. and 165°F. Since it has been established often that verticality of a vertical gyro is not proportional to free drift of that gyro, verticality of the two-gyro master reference primarily depends upon the sophistication of the erection system.

(9) Verticality of the two-gyro master reference on the bench is established within 1/4° from the local vertical. In flight in smooth air, verticality would be similar to bench verticality. In flight under conditions most disturbing to the gyro erection system (long term, high thrust accelerations, low bank turns at very high speed, etc.) errors of verticality would vary from 1° with the most sophisticated erection system to 4° with a simple conventional system.

(10) Studies of known all-attitude flight-instrument problems show that the two-gyro master reference is capable of providing all necessary basic information for their execution. It can be integrated into special-purpose bombing systems requiring a nontumbling gyro reference characteristic throughout the maneuver. It is ideally suited for use as the primary stabilization element in high-performance automatic pilot systems.

A typical two-gyro, all-attitude master reference system consists of the following components:

two-gyro master reference
servoamplifier
compass adapter (heading servo)
directional-gyro control panel
rate gyro switching mechanism
pitch-acceleration erection cutout

Several systems of this type have been developed and tested. They meet all standard functional and environmental requirements established by the military services. They provide accurate, continuous, and unambiguous reference signals throughout all aircraft maneuvers and flight modes without tumbling of the gyro references in any attitude.

A description of a prototype two-gyro, all-attitude master reference may be of interest. Over the past 4 years an advanced concept of ball-bearing gyro design has evolved. This new concept involves the use of low-cost cast- and machined-aluminum structures for the servo-driven platform gimbals and steel structures for the sensitive axes. The gyro wheels, rotor housings, and gimbals immediately surrounding them are made of steel in order to achieve maximum gyro performance over a wide temperature range. A vertical gyro of this type of steel construction has been fabricated and qualified for the USAF. It is illustrated in Fig. 2. In test, this gyro has proved most reliable. (Running times of over 2,000 hours have been recorded without malfunction or loss of gyro performance.) This basic gyro is currently in production. Approximately 40 directional gyros using the same techniques and similar structures have been assembled and tested. The tests have shown excellent drift results with the same overall reliability of the vertical gyros.

It is these basic gyro elements which are being used in the design of a prototype two-gyro control, shown with the case removed in Fig. 3. Fig. 4 is the directional gyro element of the two-gyro master flight reference ready for mounting in the outer roll gimbal. Fig. 5 illustrates the simple method of assembly possible with the parted outer roll gimbal. A typical vertical gyro element is shown in place before the end cap and roll trunnions are attached. The angular momentum of both the vertical and directional gyro rotors is approximately 8 million gm.cm.^{2} per sec. The use of rotors of such high momentum guarantees drift rates well within the limits of new aircraft requirements.

Fig. 6 is a diagram showing the arrangement of all gimbals. The directional portion of the reference is mounted in a servoed gimbal which always maintains the output (azimuth) axis of the directional gyro in a vertical attitude regardless of aircraft position. This gimbal, which is driven by a small motor generator operating from a transistor amplifier, receives its vertical reference from the vertical gyro portion of the two-gyro reference.

The vertical-sensing electrolytic erection switches (erection accelerometers) are positioned to produce the desired erection characteristics in all flight posi-

tions. Both the roll and pitch accelerometers are located on the vertical gyro rotor housing.

The steel vertical and directional gyros are mounted on a common cast aluminum roll follow-up gimbal. It employs in its design two lines of separation for ease of assembly and calibration. Aluminum is used because of its ease of fabrication into complex shapes. The roll follow-up gimbal is servoed to a position which is perpendicular to the vertical gyro spin axis. A transistor-magnetic amplifier is used to provide the power to a motor-generator which drives the gimbal at a slew rate of 360° per sec.

Tubeless-amplifier techniques have progressed to the extent that successful life tests of 1,000 hours have been completed on transistor and magnetic amplifiers at an ambient of 100°C. Since both types of amplifiers had generally been limited to considerably lower temperatures, potential system applications have been greatly broadened. The results are even more impressive in view of the fact that one test was conducted under full-amplifier-output conditions, a much more severe condition than that encountered in service.

The equipment required to provide a special outer-roll gimbal sequence of operation may be supplied in a separate package. In this mode, pitch aircraft elevation angle is sensed from the pitch synchro transmitter. When the aircraft is within 10° of vertical flight it is possible to switch the third gimbal sensing from the inner roll synchro to a case-null or zero-roll position. This zero-roll position is determined by a separate "dead head" transmitter which is locked at the zero roll position with respect to the airframe. Depending upon the mode of operation selected, the third gimbal can be made to follow the inner roll gimbal or can be made to seek a locked-to-case position.

The inner roll synchro which provides the signal for the outer roll follow-up servoamplifier is a low-impedance transmitter that can be used to supply a signal to other equipment without causing deterioration in the performance of the vertical gyro. The outer roll gimbal, together with its contents, is mounted in a casting and tubing frame. Here again low-cost techniques are utilized. The use of aluminum offers weight reduction and provides coefficient-of-expansion matching.

The two-gyro master reference is cased in a drawn magnesium can to effect the greatest possible weight saving. The reference may incorporate a quick-disconnect shock mount if desired. It can be hard mounted or mounted on a center-of-gravity or sway-bar type of shock mount; this, of course, depends upon the application. Vibration levels in most jet aircraft allow its use without shock mount.

The servoamplifier package contains the amplifiers required for directional gyro leveling, directional gyro pitch-gimbal follow-up, and roll-gimbal follow up. New transistor and transistor-magnetic amplifier designs are used for these amplifiers. Fig. 7 shows one of the small transistor amplifiers developed for this purpose. They are rugged and reliable and are capable of a minimum of 2,000 hours operation.

A typical master heading servo package includes the directional gyro slaving system. The system diagramed is designed to be within the USAF J-4 directional-gyro specifications and USN MA-1 specifications. The slaving system consists of an azimuth follow-up synchro coupled to a fast servo-motor drive capable of automatically synchronizing azimuth signals from the two-gyro reference at a minimum rate of 60° per sec. Mechanically and electrically coupled with this synchro is a differential synchro, which automatically gives proper heading information regardless of the spin-axis position of the directional gyro element. The rotor of the azimuth synchro is mechanically coupled to rotors of two heading-data-transmitter synchros and a compass-matching synchro to control the slow-slaving rate of the gyro. Many similar designs of high or low accuracy and with special features can be coupled to the two-gyro master reference.

Guiding principles in the design of a master heading servo are compactness, small size, lightness of weight, and low cost, combined with adequate performance levels. Lightweight magnesium structures are used wherever possible. Where possible the units are hermetically sealed to eliminate the effects of environmental conditions, including high altitude.

A typical directional control panel is shown in Fig. 8. A function-selector switch is provided to select the mode of operation of the compass system. When the switch is in the *slaved* position the system will operate as a magnetic compass and will synchronize with a Type C-2 transmitter. When the switch is in the *free* position, the system will operate as a latitude-corrected directional-gyro. A manually set controller is provided to correct the system, when in the *free* directional gyro mode of operation, for the apparent drift of the gyro due to the earth's rotation.

An annunciator on the panel indicates, by means of a needle pointer, the synchronization of the system within ± 1/4°. All other military and civilian requirements have been included in the design of the control panel. In addition, internal lighting of all knobs, markings, and pointers is provided.

A rate gyro switching control is provided with a typical two-gyro master reference system. This rate gyro meets all military and civilian requirements and is considerably smaller and lighter than the limits allowed. The package size is 2.0 by 2.5 by 4.5 in. and its weight is approximately 1.3 lbs. No heater is required in its operation. Two relays for right- and left-turn sensing are provided in the mechanism. These relays can provide signals for other instruments in addition to the two-gyro reference. It is planned that this unit can be mounted in the aircraft without shock mounts.

A pitch acceleration cutout device is provided for most high-performance aircraft. Maximum performance will not be achieved unless pitch erection of the vertical gyro is cut out during periods of changing air speed.

From the system elements described and illustrated a new master reference system of maximum simplicity

XUM

has been built. The two-gyro master reference system is available *today* for new high-performance aircraft currently going into production. It is not in any sense a dream or a vision in the eyes of research organizations.

Installation of a two-gyro reference system in any new jet aircraft will provide the many benefits of all-attitude indication and, equally important, will offer stable azimuth information.

The two-gyro master reference is an important instrument in the transition from the present use of individual gyros to the elaborate master reference concept. It is broad in its scope yet simple in philosophy. Fabrication costs fall between present gyro costs and the very high prices presently asked for advanced stable platform systems. The role of the two-gyro master reference is obvious. It is an introduction to master references, providing their primary feature of all-attitude reference without their present complexity and cost.

Early use of the two-gyro master reference in new aircraft need not limit future instrumentation of later models of those aircraft. There is considerable growth potential in the two-gyro master reference system. First, and of considerable importance, the present verticality of the vertical gyro element canbe greatly improved by the addition of a compensated sensing pendulum and the use of integrators in the erection system. Calculations show that with the use of sophisticated vertical gyro-erection systems, day-in, day-out verticality of better than 1° can be expected *under any maneuvering conditions.*

It has been found practical to substitute a very low drift floated gyro element for the ball-bearing suspended directional gyro of the two-gyro master reference. A minimum of changes in the two-gyro master reference structure is required to substitute a high accuracy floated directional reference. While floated elements are planned primarily for advanced design stable platforms, current indications are that they will be available several years before the complete platform of which they are a part. Introduction of floated directional gyro elements would in no way affect the external directional gyro system already developed for the two-gyro master reference.

These and many other improvements are on the drawing board and in the laboratory, planned for orderly introduction into an already bench- and flight-proven two-gyro master reference system. Such improvements will insure a long, useful life for the instrument in advanced jet aircraft.

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Stretched Acrylic *(Continued from page 46)*

[4] Hiltner, J. R., *Recent Progress in the Development of Multiaxially Stretched Acrylics*, Paper presented at the Fifth Transparent Materials Conference WADC, September, 1953.

[5] Gouza, J. J., and Hurst, D. A., *The Investigation of Multiaxially Stretched Acrylic Plastic*, WADC TR 54-619 Pt. 1, Wright-Patterson AFB, Ohio, December, 1954.

[6] Stansbury, J. G., *Progress in the Development of Stretched Transparent Materials*, Paper presented at the Sixth Transparent Materials Conference, WADC, March, 1955.

[7] Kies, J. A., *Aircraft Glazing Materials—A Method for Evaluating the Shatter Resistance of Aircraft Canopy Materials*, NRL Memorandum Report 237, Washington, D.C., November, 1953.

[8] Kramer, M. J., *A Study of the Birefringence of Hot Stretched Polymethyl Methacrylate*, NRL Report 4751, Washington, D.C., June 21, 1956.

[9] Schiff, E., and Olds, W. E., *Canopy Material Development Model F102*, Report No. 8706 Progress Reports No. 1 thru 13, Convair, A Division of General Dynamics Corporation, San Diego, Calif., January 1, 1955–December 5, 1956.

[10] Aircraft Research and Testing Committee: *Test Methods for Stretched Transparent Thermoplastic Enclosure Materials*, June 18, 1956. Addendum to Aircraft Technical Committee Report ARTC-8, Aircraft Industries Association of America, Washington, D.C.

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The Turbine Engine in Salt Atmosphere Operation *(Continued from page 49)*

ing, and the insignificant results of additional shellings (Figs. 7 and 8).

The Sea Dart program is one of hydrodynamic research. It is designed to investigate ski configurations never tried in full-scale before. Each operation, from launching to beaching, involves five or six taxi runs, take-offs, and landings. Some of them are rather damp. Progressive blade contamination during one of these operations causes as much as 10 per cent reduction in airflow, 300 r.p.m. drop in idle speed, turbine inlet temperature 40°F. in excess of red line, and 300 lbs. reduction in maximum thrust. To eliminate these losses, an integral fresh water injection system was developed.

The aft fairing of the pilot's canopy is utilized as an integral 18 gal. tank. An electrically driven pump delivers fresh water directly into the engine air-inlet duct about 10 in. aft of the lip. A switch in the cockpit permits the pilot to select either engine when the need arises and inject fresh water at a rate of $3^1/_2$ g.p.m. at 15 psig. About 1 gal. of water per engine after each take-off and landing has been sufficient to maintain engine performance at rated values throughout these operations. This system has also reduced the need for walnut shelling engines on the beach.

Engine reliability is good. Engine life between removals has been increased to 30 test operations. This is equivalent to 170 take-offs and landings.

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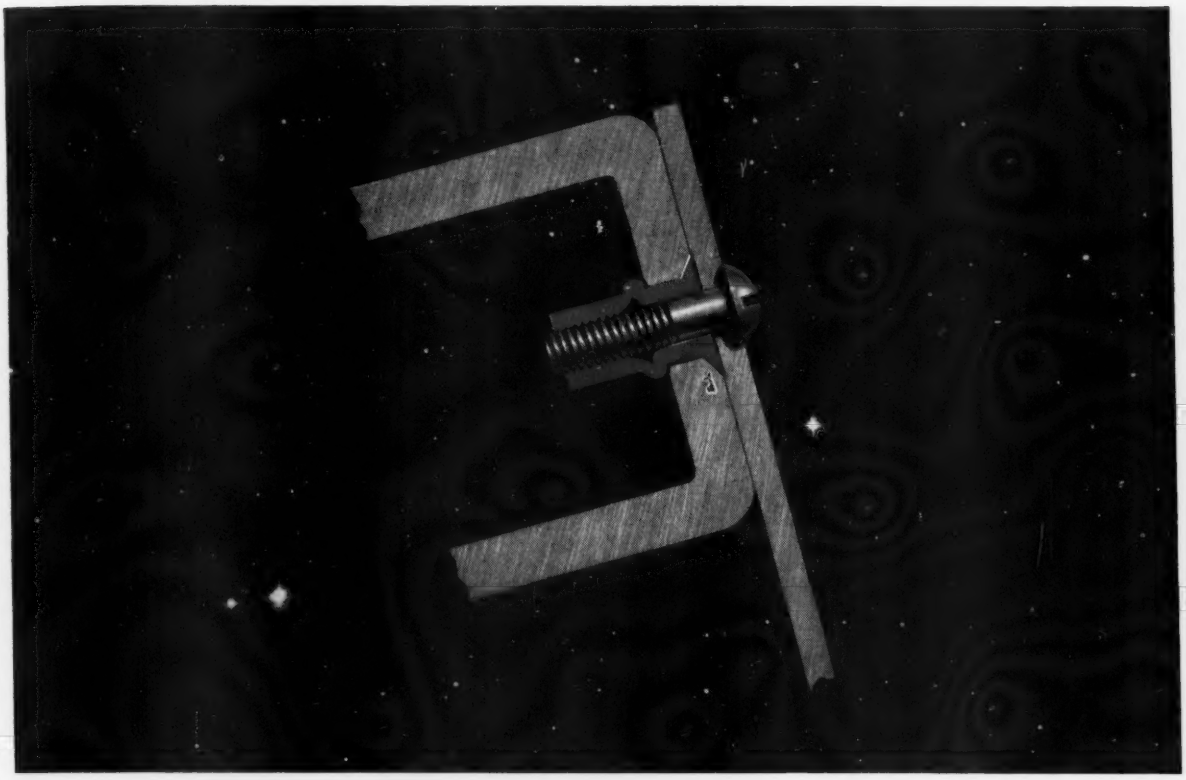
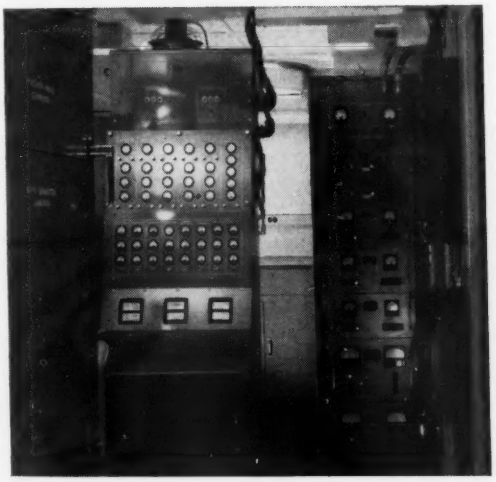


Rivnuts provide sturdy blind nutplates for ultra-sensitive equipment that will receive radio impulses from Vanguard Satellite



During the International Geophysical Year, scientists will launch the first American satellite, the Vanguard. To track its orbit around the earth, "Minitrack" stations in North and South America will receive radio signals from the satellite itself, magnify them with ultra-sensitive receivers, and relay position information to the Vanguard Computing Center in Washington.

The photograph (left) shows the inside of a "Minitrack" station, with the receiver rack in the center. Fastening the face panels on this rack posed a problem for Bendix Radio Division, manufacturers of the equipment. Because the frame is made of square tubular aluminum for greater strength, ordinary nuts and bolts could not do the job.

Bendix found the answer in B.F.Goodrich Rivnuts, which provided sturdy, blind nutplates, easy and economical to install. Whatever you manufacture, from complex electronic equipment to simple sheet metal assemblies, B. F. Goodrich Rivnuts may be the answer to your most puzzling fastening problems.

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light" test system that tells when the weapon is ready for firing. Component operation is recorded by red and green lights on test equipment according to the firm. Talos also is being evaluated by the Army.... Eclipse-Pioneer Division has opened a new sales office in Miami, Fla., headed by Lloyd Wilson. The firm has named R. J. Creagan to head its nuclear program; he worked on the Nautilus reactor development. E. C. Cooper has been named General Manager of Bendix West Coast Sales and Service.

• **Boeing Airplane Company** has completed its first production model 707 Jet Stratoliner, the first production-line commercial jet built in this country, according to the firm's Transport Division.

• **Chance Vought Aircraft, Incorporated,** has created a new division devoted to advanced weapons engineering on a status comparable to its aircraft and missile divisions. Its officers are A. L. Jarrett, Manager, formerly Chief of Development Section; E. V. Marshall, Supervisor, Aircraft Design Group; and J. W. Ludwig, Chief, Advanced Missiles. The firm also has established a Programs Management Department, an integrated contracts management organization headed by H. B. Sallada, formerly Executive Vice-President and now Senior Vice-President. The firm has developed what it calls a unique tool inspection method said to reduce jig "down time" in production of the F8U-1 Crusader. Kelly G. Smith has been named Quality Control Manager and George Gasper, Chief Tool Engineer.

• **Cornell Aeronautical Laboratory, Inc.,** reports that it has transmitted microwave or radar-like signals said to be many times more powerful than believed possible (17 million watts peak power radiated) during research on Army missile systems.

• **Douglas Aircraft Company** reports that wing-joining of the first DC-8 has taken place at its Long Beach Division. A 27,000-lb. sweptback wing was joined to the 19,000-lb. fuselage.... Tulsa Division engineers are developing what they call a revolutionary method of moving heavy loads by floating them on a cushion of pressurized air—by employing conventional-type cargo pallets which actuate individual valves in a low-pressure air system.... El Segundo Division has announced the "free deck launch" of the Douglas F4D Skyray from the British carrier H.M.S. "Ark Royal." The non-catapult take-off was said to be remarkable, considering the aircraft's size and weight (20,350 lbs.). An additional 14,000 lbs. thrust from an afterburner aided the take-off. General Ira C. Eaker, USAF (Ret.), has been named to a newly created post, Director of Eastern Offices. All sales activities have been consolidated under the direction of Nat Paschall, previously Vice-President—Commercial Sales, and all flight and testing activities under Arthur E. Raymond, Vice-President—Engineering.

• **Edo Corporation** has announced a revision of its licensing agreement with Bristol Aircraft (Western) Ltd., of Winnipeg, Canada, providing that all Canadian requirements for all Cessna and Piper float models will be supplied by Edo from College Point, N.Y. Bristol will continue to manufacture Edo-designed standard and amphibious floats for de Havilland Beavers and Otters and other custom-built floats. The firm also has announced receipt of an order for 53 Loran units from Pan American World Airways, Inc.

Bell Helicopter Corp. has developed this helicopter flight simulator to test an electro-mechanical contact analog generator built for Bell by Allen B. DuMont Laboratories, Inc. Bell says its contact analog produces a synthetic representation of the outside real world on a screen mounted in the helicopter and will permit day and night operation in all but the most severe weather.

The wing and fuselage of Douglas Aircraft Company's DC-8 are shown being joined at the firm's Long Beach, Calif., assembly building. The 19,000-lb. fuselage was lowered to receive the wing. Wing span will be 139 ft. 9 in.

A model of the first supersonic basic trainer, Northrop's T-38, is shown being prepared for testing at Cornell Aeronautical Laboratory's 1,000 m.p.h. wind tunnel. Preparation is to measure the aircraft's aeroelasticity characteristics.

• **Fairchild Camera and Instrument Corporation** is sponsoring a new firm, for development and production of silicon-diffused transistors and other semiconductors, named Fairchild Semi-Conductors Corporation.

• **Fairchild Engine and Airplane Corporation,** Stratos Division, has established an Advanced Products Planning Group whose objective is to anticipate future requirements in the aircraft and missile equipment and accessory system fields, according to the firm. Jerzy Makowski, former Chief Research Engineer, will head the new group.

• **The Garrett Corporation's** AiResearch Manufacturing Division, Los Angeles, Calif., has developed a combination fuel heater and fuel filter for the DC-8, said to

Cooling for electronic reliability...by AiResearch

SPECIFICATIONS

COOLING CAPACITY	Full 1.5 kw at 50,000 ft. ambient pressure altitude and inlet conditions as follows:
AMBIENT AIR	TEMPERATURE: 10°C. PRESSURE: 1.7 psia FLOW: 3.6 lb/min
CONTAINER GAS	TEMPERATURE: 85°C. PRESSURE: 20 psia FLOW: 9.8 lb/min

The AiResearch unit shown above solves another critical electronic cooling problem in the following manner:

The larger fan, at top left of unit, draws cooling ambient air through the heat exchanger. Simultaneously, the smaller fan, at bottom center of unit, circulates dense, non-toxic sulfur hexafluoride (SF_6) through the heat exchanger and over the electronic equipment. The cooled gas maintains the sealed electronic equipment at the desired temperature.

The 20 by 24 inch honeycomb mounting base for the cooling components is designed by AiResearch to form an integral part of the pressurized electronic equipment container.

This cooling package, incorporating standard, proved components, was developed by AiResearch in minimum time. It and other air or liquid-cooled units for similar purposes are based on almost 20 years of experience in the development of cooling systems for aircraft, missile and nuclear applications.

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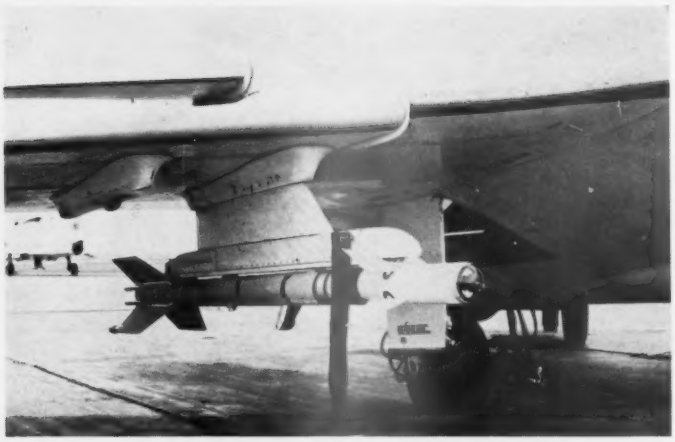

The Navy's Sidewinder air-to-air missile, shown mounted under the wing of a Grumman F-9-F, is guided by General Electric Company's "passive" infrared device, produced by the Light Military Electronic Equipment Department. The missile is said to be so accurate it can shoot a flare-pot off the wing of a drone target planer.

weigh 27.5 lbs. The division also is providing pressurization equipment for the JetStar and On Mark Model 450 transports. Charles W. Leinbach, Jr., has been elected Secretary of the company. George F. Rice has been named Chief Engineer, AiResearch Aviation Service Company. J. J. O'Brien has been appointed Manager, AiResearch Manufacturing Company of Arizona.

• **General Dynamics Corporation...** Convair Division (Fort Worth) has announced completion of a new hydraulic and pneumatic pressure test building with seven specially built test cells for aircraft research, development, and component evaluation tests. Krafft A. Ehricke, Assistant to the Technical Director, Convair (Astronautics), has proposed an International Astrophysical Decade during which space would be probed with special unmanned vehicles. The suggestion was in the form of a paper delivered at the Eighth Annual Congress of the International Astronautics Federation in Barcelona. Convair (San Diego) has named Alan W. Abels Manager—Export Sales and C. Gordon Wolcott, Manager—Domestic Sales....Canadair Limited (Subsidiary) announced plans for a commercial version of the turboprop CL-44 military transport. Dimensions and characteristics: 137 ft. long, 142-ft. wing span, 205,000 lbs. max. gross take-off weight, 86,121 lbs. empty (cargo), 101,194 lbs. empty (passenger), 10,036 imperial gal. fuel capacity, 445 m.p.h. max. cruise speed, 5,000 miles max. range, and power by four Bristol Orion turboprop engines. Delivery is scheduled for 1960. Canadair's Nuclear Engineering Department plans to install Canada's first subcritical reactor for educational purposes at the University of Toronto.... Stromberg-Carlson Division has named Brig. Gen. William L. Bayer, USA (Ret.), Manager—Military Marketing, Electronics Division. Henry M. Taylor has been named Manager of Marketing—San Diego....Electric Boat Division reports that the first production-type atomic submarine, U.S.S. "Skate," has completely sea trials....General Atomic Division will build a nuclear reactor said to be the first designed for custom production of radioisotopes as well as training and research. Peter Fortescue, who contributed to Britain's Calder Hall Power Reactors, has been named Chief Research and Development Engineer. A booklet on the history of nuclear energy development, *The Atomic Revolution*, has been published and is available from General Dynamics on request.

• **General Electric Company...** Aircraft Gas Turbine Division reports that its T58 engine has been accepted by the Navy after its 150-hour model test.... Apparatus Sales Division, Atomic Power Equipment Department, has published six new bulletins on components for liquid metal systems. The components are for use in nuclear, metallurgical, petroleum, and chemical fields and are pumping, purification, and indicating components for liquid sodium and sodium potassium systems....Defense Electronics Division, Light Military Electronic Equipment Department, has announced the appointment of Donald A. Garr, Manager—Engineering Operations, and Carl A. Beers, Manager—Employee and Community Relations.

• **General Precision Equipment Corporation** has named Raymond L. Garman Vice-President—Engineering and Research. Dr. Garman also is Chairman of the Board of General Precision Laboratory Incorporated, an affiliate.

• **G. M. Giannini & Co., Inc.,** is manufacturing a Precision Voltage Monitor said to reduce normal telemetering and recording system errors from 4 or 5 per cent to 0.04 per cent or less.

• **The International Nickel Company, Inc.,** has established a Chair in Chemical Metallurgy at Columbia University with an initial grant of $350,000 and an additional $75,000 for special expenditures.

• **Johns-Manville Sales Corporation** is marketing a new Chempac Teflon Clipper Seal said to provide positive sealing in the presence of and in contact with active solvents and corrosives. A brochure on the new product, *J-M Chempac Packings and Gaskets*, is available at Dept. PK 124A, Johns-Manville Corporation, 22 E. 40th St., New York 16, N.Y.

• **Kelsey-Hayes Company** has added Heintz Manufacturing Company to its divisions and will continue to operate the firm as the Heintz Division. Current management has been retained, and Reese Lloyd, Heintz President, has been appointed Vice-President of Kelsey-Hayes, the company announced.

• **Koppers Company, Inc.,** has announced the appointment of D. B. Callaway as Chief Engineer, Industrial Sound Control Department.

• **Lear, Incorporated,** has designed an autopilot (L-102) said to feature advanced miniaturization techniques, sophisticated circuitry and packaging, and weight-size permitting installation of two units in the same space as any other single jet transport autopilot. The firm also announced it is manufacturing "the smallest self-contained microsyn avail-

Grumman Aircraft Engineering Corp. displayed this mock-up version of the Army's AO-1 "Mohawk" observation plane as part of the Army Association Annual Meeting. Lycoming T-53-L-3 turboprop engines will power the aircraft which has a wing span of 42 ft. and is 42 ft. 9.5 in. long. Take-off power for each engine is 1,005 e.s.hp.

All-weather flight for Helicopters

Sperry Announces Advanced Developments in Controls

To increase the all-weather capability of helicopter flight has been a continuous research and development program at Sperry. The newest development is a Stabilizing Control System adaptable to all types of rotary wing aircraft.

This new miniaturized electronic system is designed for partial or fully automatic control to achieve stability during take-off, in flight, hovering and landing – in varying conditions of wind and weather. Use of transistors, redundant amplification and rugged miniaturized components, engineered with traditional Sperry precision, give the new system great accuracy and reliability—all within small space and light weight for either the minimum or fully automatic system.

CHIEF BENEFITS OF THE NEW SYSTEM ARE:

Reduction of pilot fatigue. Constant stick handling is eliminated.

Accurate navigation. Precise flight is achieved even under conditions of poor visibility and over unfamiliar terrain.

All-weather flight. Automatic system provides hands-off stability needed under all flight conditions.

Control stick steering. The pilot generates command signals by moving stick in conventional manner.

Other Sperry developments for helicopters include a new Sperry All-Weather Integrated Instrument System. Providing simplified display of all data for manual control, it includes Flight Director Computer, Horizon Flight Director Indicator, Navigation Computer, Compass Pictorial Displacement Indicator, Altitude Vertical Rate Indicator and RPM Control System (also available individually). If you have a requirement in helicopter controls and instrumentation, write our Aeronautical Equipment Division.

AERONAUTICAL EQUIPMENT DIVISION

SPERRY GYROSCOPE COMPANY
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DIVISION OF SPERRY RAND CORPORATION

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able." An aircraft flight instrument "which combines the functions of a flight director and attitude indicator" also was announced.... James P. Brown has been named Manager—West Coast Operations, Grand Rapids Division.... Lear-Romec Division is manufacturing Model RG-18040 Series, Air Pressure Switches for all types of airborne radar pressurization sets, meeting MIL-S-9395 (USAF) requirements. John E. McKeighen has been named Contracts Manager of the division. Robert H. Essig has been appointed Assistant Contracts Manager.

• **Librascope, Incorporated...** President Lewis W. Imm has been awarded the highest Navy civilian citation, The Navy Distinguished Public Service Award, for his personal contribution of time and effort in the fields of fire control techniques and naval ordnance engineering.

• **Lockheed Aircraft Corporation** reports its F-104A Starfighter uses "boundary-layer control" which enables it to "land in less distance than any present-day jet fighter, at touchdown speeds only moderately higher than trainer rates." The firm also reports five Electras are in final assembly and that the plane will have new high-strength, lightweight, "stretched Plexiglas" windows.... Missile Systems Division has announced a new analog computer (PACE) said to weed out unworkable designs quickly and accurately by simulating the flight characteristics. The division also announced that a new shock tube to test missile designs at 13,000-m.p.h. speeds is in operation. Division scientists have launched a study of sending and receiving radio and radar signals in outer space in a new space communications laboratory at Sunnyvale, Calif.... Georgia Division will be used by USAF's Institute of Technology for on-the-job training of officers at management and policy levels. The division has received orders for twelve C-130 transports from the Royal Australian Air Force, the first foreign sale of the aircraft, the firm reports. B. B. Bundesman has been named Jet-Star Commercial Sales Manager. The division also named four military sales managers: Douglas P. Wheeler, contracts; David T. Crockett, Jr., developments; James B. Constable, modification and ANP manned aircraft; and William D. Perreault, exports.

• **Manning, Maxwell & Moore, Inc.,** has named Jack S. Verhaeghe Technical Adviser, European Area, Export Division.

• **The Martin Company** has developed a grid layout table and tracer control device on the Wales semi-automatic hole-punching fabricator said to save seven man years per year.

• **Northrop Aircraft, Inc.,** has announced the appointment of Robert Lee Snider, former SAC Assistant Director of Operations, to the post of SAC Headquarters Representative. Arch Wallen has been named Factory Manager, Northrop Division.

• **Pan American World Airways, Inc.,** has added six European cities to its all-cargo service: Brussels, Amsterdam, Dusseldorf, Stuttgart, Munieh, and Berlin.

• **The Ramo-Wooldridge Corporation** has established a Computation Consulting and Service Bureau to provide scientific computation and mathematical analysis service for business and industrial organizations. The Bureau will be operated as part of the firm's Digital Computing Center, Computer Systems Division. This division has developed a new digital airborne computer said to provide a lightweight, compact computing-control center for high-performance military aircraft. Designation is RW-30.

• **Reaction Motors, Inc.,** has shown publicly a new integral, self-contained liquid propellant rocket engine package at the Third Annual Meeting of the Association of the U.S. Army. One of the unit's main features is said to be flexibility in operational characteristics—choice of propellants, duration of firing, thrust level. David Eaton has been named to the newly created post of Vice-President—Marketing.

• **Republic Aviation Corporation** has established a Commercial Contracts Division to provide engineering, development, and manufacturing services to industry generally and as a supplier to other aviation companies and skilled industries. Brigadier Gen. John M. Sterling, USAF (Ret.), has been appointed Assistant to the Vice-President for European Operations.

• **Ryan Aeronautical Company** has announced plans to double the floor space of its Torrance, Calif., division. Ryan also plans to move its electronics section into a new 30,000-sq.ft. building leased from Magnatron Corporation in downtown San Diego.

• **Shell Oil Company** has constructed a 3.36 million gal. gasoline storage tank at Frobisher Bay Airport, Baffin Island, for refueling commercial aircraft flying the polar route. Shell also has produced a new film *Song of the Clouds* portraying the service performed by world air transport through the International Air Transport Association and the International Civil Aviation Organization.

• **Solar Aircraft Company** has licensed the Swedlow Plastics Company to manufacture and sell its resistance-welded stainless steel honeycomb core in the United States and Canada. Solar also has made available a new brochure *Solar Advanced Technology* that may be obtained from the firm at 2200 Pacific Highway, San Diego 12, Calif.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation** has opened a new USAF liaison office in Dayton, Ohio.

• **Union Carbide Corporation,** National Carbon Company Division, reports that molded shapes of activated carbon are now commercially available for the first time.

• **United Air Lines, Inc.,** has ordered a closed-circuit television system flight simulator which is said to unfold an airport panorama in front of pilots as they "land" or "take of." The system will be part of a DC-8 jet transport simulator manufactured by Link Aviation, Inc.

• **United Aircraft Corporation,** Hamilton Standard Division, formally dedicated what the firm calls the largest facility in the East for development and production of fuel controls for turbine, atomic, and rocket engines—410,000 sq.ft. of engineering, manufacturing, and testing space at Windsor Locks, Conn. Several promotions were announced in connection with the opening of the new facility (Building 2): Robert A. Earley has been named General Superintendent of Manufacturing and Harold A. Rourke, Superintendent of Experimental Manufacture. The division also announced establishment of a separate department of Service Overhaul and Repair with S. B. Sherwin as Manager.

• **Vickers Incorporated** has announced the appointment of William J. Herrmann as Manufacturing Manager, Aero Hydraulics Division.

• **Westinghouse Electric Corporation** Research Laboratories has announced a new magnetic steel called Cubex steel—doubly or cube-oriented silicon-iron. The firm reports that a unique crystal arrangement permits easy magnetism in four directions, permitting magnetism to "turn corners" in the magnetic core of a piece of electrical equipment. Scientists of the firm also have developed a technique for preparing ultrapure niobium, called "cage zone melting," by refining it at 4,400°F. in a vacuum four billionths the pressure of atmosphere.... Aviation Gas Turbine Division has announced completion of a new jet fuel storage and handling system at its Kansas City facility. Frank H. Robbins has been named Director, Development and Production Engines.

IAS SECTIONS

Baltimore Section

Suspended in Space For 32 Hours

How it feels to spend 32 hours at an altitude of 100,000 ft. was described by Major David G. Simons, USAF, before a record Baltimore Section turnout of 750 members and guests on October 17.

Major Simons, Chief of the Space Biology Branch, Aero-Medical Field Laboratory, USAF Missile Development Center, was suspended at that altitude in a sealed gondola below a 3-million-cu.ft. balloon during Operation Manhigh II.

Major Simons said the purpose of the flight was to gain experience and to test the reactions of a human being in a completely hostile environment—similar to that which would be experienced in a manned satellite or space vehicle.

Also at the meeting were members of the Maryland Academy of Sciences and the Research and Development Squadron of the Air Force Reserve.

DAVID W. LUECK, *Secretary*

Boston Section

Magnetic Field Alters Aerodynamic Forces

Arthur Kantrowitz explained "Magneto Hydrodynamics" at the first fall meeting held at Massachusetts Institute of Technology, October 22. Dr. Kantrowitz is currently Visiting Institute Professor and Fellow of M.I.T. School of Advanced Studies. He is on leave from his position as Vice-President and Director, Avco Manufacturing Corporation.

His talk was prefaced by slides of a cylindrical body with copper nose cone that was subjected to simulated high Mach Number flow. The slides were used to define aerodynamic heating problems and illustrate the destructive capability of severe aerodynamic heating.

Dr. Kantrowitz began his explanation by relating magneto hydrodynamics to the heating problem, saying that high-temperature gases around bodies at very high speeds are ionized and conducting. He said it is possible to alter the aerodynamic forces and heat transfer in the vicinity of a body in such a flow by introducing a magnetic field force. The stable coupling between the magnetic and aerodynamic forces results in the phenomenon called magneto hydrodynamics (MHD).

A quantity called magnetic Reynolds Number was derived from relationships involving field strengths, conductivity, velocity of flow, and geometry. This is the product of conductivity, velocity, and a length. Dr. Kantrowitz said it was noted that this parameter plays the same role in MHD flow as the Reynolds Number does in normal viscous flow. The same relationships indicated the need for large amounts of electrical energy to produce the necessary magnetic field strengths.

This requirement led to the speculation of operating a moving conductor (coil) as a self-exciting generator to supply the electrical energy.

Dr. Kantrowitz described characteristics of such a generator to establish a criterion for predicting conditions when self-exciting generation may occur. He said heating from large electric currents in the generator could exceed the reduction in aerodynamic heating due to MHD.

He explained the flight regimes of MHD in terms of altitude and velocity by defining further relationships between magnetic force and dynamic pressures. He showed that turbulent heat transfer at the lower altitudes produces a discontinuity in the lower boundary of the MHD regime. The velocity at which self-exciting generation starts is below the velocity at which MHD can occur. Seeding the air with potassium could conceivably extend the lower region of MHD from about Mach 10 to about Mach 3.

In conclusion, Dr. Kantrowitz showed slides of high Mach flow around a ballistic body with and without the presence of a magnetic field. Bulging of MHD flow-away from the body was pronounced and impressive. The experiments depicted were conducted in a shock tube device (gas accelerator) capable of producing high shock velocities and temperatures needed to study MHD.

The temperature behind an initial shock in the gas generator is about one-half million degrees and behind the reflected shock about a million degrees. Also, it is difficult to retain high-temperature gases in the vicinity of the moving conductor for high magnetic Reynolds Number flow, and, as a result, a less stable flow is experienced.

New Section officers introduced during the business meeting were John B. Tucker, Chairman; Elmer E. Larrabee, Vice-Chairman; Gaetano Falabella, Jr., Secretary; and Daniel J. Fink, Treasurer.

G. FALABELLA, JR., *Secretary*

Dayton Section

B-58 as Weapon System

The B-58 was described as basically a two-component weapon system by J. T. Cosby, Convair's B-58 Program Director, before 200 members and guests at the September 19 meeting.

The upper component is a delta-wing airplane powered by four General Electric J-79 engines, he said. The lower component is a pod which serves as a fuel tank, weapons, and equipment carrier.

J. T. Cosby

Convair, as USAF's weapon system manager for the B-58, had to match each subsystem to the program concept rather than use USAF subsystems at hand. The Air Force gave Convair the responsibility for all subsystems except the engines—the first time this has been done with a man-carrying military aircraft, according to Mr. Cosby. Convair's total subcontractors and suppliers number in the thousands, he said. He ended with a film of the first B-58 flight.

JOHN S. MCCOLLOM, *Secretary*

Detroit Section

Bleed Air Control

A technical paper on jet-engine bleed air and an after-dinner talk on the second Byrd Antarctic expedition (1933–1935) were heard by 53 members and guests at the September 25 meeting.

The paper, "The Utilization of Jet-Engine Bleed Air in Aircraft and the Design and Development of the Bleed Air Controls" by D. Schumann and J. F. Hill, was presented by Mr. Schumann. Mr. Hill is Chief Engineer and Mr. Schumann Project Engineer, Janitrol Aircraft Division, Surface Combustion Corporation. Mr. Hill spoke on the Byrd expedition.

Mr. Hill, who was the youngest member of the Byrd expedition and coauthor of *In Little America With Byrd*, illustrated his talk with slides.

A gift was presented to the Section's past chairman, Ludwig Majneri, by Chairman S. B. Williams, in appreciation of his work in the Section.

RICHARD CHUTE, *Secretary*

Hampton Roads Section

Nuclear Research For Aircraft Propulsion

"The Nuclear Reactor as a Research Tool" was discussed by H. A. Lamonds, Director, Reactor Project, North Carolina State College, at the September 26 meeting.

He began with the physical structure of chemical elements and went on to describe the fission process, some fissionable fuels, breeders used to start the process, moderators and coolants, and the physical design of solid fuel and gaseous reactors.

Mr. Lamonds described "shadow shielding" as a means for reducing ANP weight. This consists of fore and aft shielding of the reactor alone, with conventional propulsion systems for ground or low altitude operation. Such a method requires foolproof switching and instrumentation for air-crew and ground-crew safety.

His talk was concluded with a question and answer period.

PAUL A. HUNTER, *Secretary*

Kansas City Section

Two Military Engines Combined in CJ-805

Ray T. Lewis, Commercial Sales Manager, Aircraft Gas Turbine Division, General Electric Company, presented a verbal blueprint of his firm's CJ-805 commercial turbojet engine before 36 members on October 15.

Design of the CJ-805 was guided by the simplicity, small frontal area, ruggedness, light weight, and good maintainability of the J-47 combined with those features of the J-79 engine which produce a low specific fuel consumption and high thrust-to-weight ratio.

Access requirements in the front of the engine were eliminated to cut down the chance of workmen dropping tools and parts which might be ingested.

The single-spool compressor section design was the result of comparison with two-spool compressors. The single-spool with variable stators was selected to permit adoption of J-47 features which improve overall reliability. The variable stator feature is combined with a conical shaft arrangement to permit a gain in weight of some 10 per cent without sacrificing ruggedness. Several stages of shrouded and unshrouded stators added durability to the compressor.

"Project Vanguard, IGY Satellite Development" was the subject discussed at the Washington Section September 19 meeting. *Left to right* at the guest table are: Gerald L. Desmond, Section Vice-Chairman and Program Chairman; Leonard Arnowitz, speaker, The Martin Co.; John P. Hagen, speaker, Vanguard Project Director; Rear Adm. Rawson Bennett, II, Honorary Chairman; Capt. A. B. Metsger, USN, Section Chairman; The Hon. Garrison Norton, Assistant Secretary of the Navy for Air; George M. Bunker, President, The Martin Co.; Rear Adm. W. A. Schoech, BuAer Deputy and Assistant Chief; S. Paul Johnston, IAS Director; and Boyd Myers, Section Treasurer.

Mr. Lewis said that G-E is of the opinion that a fully shrouded compressor loses some efficiency but that shrouded stators in the early stages protect against foreign object damage. This feature also is improved by using fabricated blades which tear rather than come loose from the rotor. The engine also has a steel case to retain blades in the event of compressor failure.

A member of the Advisory Board, V. V. Schloesser, presided over the meeting because all Section officers were out of town. Members of the Trans World Airlines, Inc., Powerplant Staff substituted for Program Chairman S. L. Higginbottom who also was out of town. Norman Parmett of TWA introduced Mr. Lewis.

J. R. MACPHERSON, *Secretary*

San Francisco Section

Thermal Effects on Structures

Nicholas J. Hoff, Head, Division of Aeronautical Engineering, Stamford University, discussed "High-Temperature Effects on Structures" at the October 17 dinner meeting.

Professor Hoff covered temperatures encountered, material properties under elevated temperature conditions, and constructional features that control temperature gradients and thermal stresses.

He spoke about plastic deformation and the additional dimension—time. He illustrated the overpowering effect of temperature history on structural life when the temperature rises.

Professor Hoff provided witty asides to the technical content of his talk which ranged from hilariously improbable parallels, to structural problems, to a thoughtful consideration of the philosophic implications of recent technical events.

ROBERT M. CRANE
Secretary

Tulsa Section

Commercial Jet Cost Is 55 Per Cent Engine

"A Study of Engine Characteristics Best Suited for Commercial Operation" was discussed by Franklin W. Kolk before 60 members and guests on October 8. Mr. Kolk is Research and Development Engineer, Equipment Development Group, American Airlines, Inc., New York.

He said 55 per cent of the costs of a typical jet transport are directly connected with the engine and its operation. Formulas were developed for an evaluation of each unit overhaul cost and the allowable time between overhaul and premature removal rate, he said. Based on changes in engine reliability, a given engine could cost as high as $75 an hour and as low as $13 a year.

The best possible compromise between engine weight and specific fuel consumption is necessary. Another important consideration is "holding fuel" at the destination. He said this in general has been unrealistically evaluated by both airframe and engine manufacturers. It will be impossible in the near future for all carriers to hold simultaneously at 20,000 ft. Hot days present another problem.

Mr. Kolk said such configurations as the by-pass engine, turboprop, and ducted fan must have preliminary design evaluations.

J. T. FARRAH
Recording Secretary

Washington Section

Four Vanguard Vehicles To Collect Space Data

John P. Hagen and Leonard Arnowitz got the Section off to an auspicious start this fall with a discussion of "Project Vanguard, IGY Satellite Development" on September 19. Dr. Hagen is Project Director for Project Vanguard. Mr. Arnowitz, who spoke first, is Assistant Project Engineer, Flight Path Control, Project Vanguard.

He described the precision control devices for the earth satellite, relating their importance to the launching vehicle. He illustrated the orbit, showing its elliptical path in detail, and mentioned the structural problems encountered in construction of three sections of the launching vehicle.

Dr. Hagen, who is responsible for the direction and coordination of the project within the Naval Research Laboratory, discussed exploration of outer space with a satellite and gave details of how Vanguard would be launched. He said four vehicles would be launched to conduct separate experiments. Data to be collected from these will cover the sun's ultraviolet radiation, cosmic ray intensity, erosion of the satellite's surface, satellite drag, and magnetic effects.

Honorary Chairman for the meeting was Rear Adm. Rawson Bennett II, Chief of Naval Research, who introduced the speakers. Guests at the meeting were the Honorable Garrison Norton, Assistant Secretary of the Navy for Air, and Rear Adm. William A. Schoech, Deputy and Assistant Chief, BuAer.

FLOYD J. SWEET, *Secretary*

Wichita Section

VTOL-STOL Reviewed

"VTOL-STOL Aircraft" were surveyed by Lee C. Landphair before 93 members and guests at the October 2 dinner meeting. Mr. Landphair is Project Aerodynamicist for the X-14 at Bell Aircraft Corporation.

He discussed tailsitter jets, rotating engine, rotating wing, boundary-layer control, and highly deflected flap aircraft. He described characteristics of the X-14 and those of aircraft in three regimes of flight: zero forward velocity, velocity greater than zero but less than stall, and velocity greater than stall.

Mr. Landphair said the X-14 is the second VTOL research vehicle constructed by Bell. Both were made of commercially available components to minimize cost. The approach adopted with the X-14 is to rotate or deflect the thrust while the airframe and jet engine remain horizontal.

This was the first meeting of the 1957-1958 season. The Chairman introduced new members of the Institute, Associate Fellows in the Section, and past chairmen. Dean Kenneth Razak of Wichita University had invited all members to a meeting of the American Society for Engineering Education in Manhattan, Kan., in October. Wichita University Student Branch was represented by Chairman Cliff Folinson, Secretary-Treasurer Dick Moracle, and Program Chairman Larry Schneider.

HOWARD W. SMITH, *Secretary*

STUDENT BRANCHES

Aeronautical University

New officers for the fall semester were elected on October 1. They are: Chairman, Edward Bartozsik; Vice-Chairman, Duncan Mulholland; Secretary, Robert Gallagher; and Treasurer, Joe Sojka.

▶ Movies of the first flight of the B-58 Hustler were shown at the September 23 meeting. A film on the Bell X-2 also was shown.

ROBERT GALLAGHER, *Secretary*

Agricultural and Mechanical College of Texas

New Branch officers elected at the first meeting of the fall semester on September 24 were Bill Welch and Charles McKinley, Engineers Council Representatives and Bill Rudderow, Secretary.

After the business meeting a movie, *Foreign Object Ingestion in the J-57 Engine*, was shown.

WILLIAM A. RUDDEROW, *Secretary*

Iowa State College

At the October 30 meeting, students who worked for aircraft firms during the summer described their experiences.

Bendix Aviation Corporation supplied the film *Air Power, 1956* which covered the National Air Show of that year. The other movie was *Air Proving Ground* from the Air Force.

▶ The October 16 meeting consisted of talks by a group of engineering students at Iowa State who had worked for aircraft firms during the summer.

JOHN ANDERSON, *Secretary*

Louisiana State University

The Strategic Air Command, an Air Force film, was seen by 20 members at the October 17 meeting.

Chairman, Ralph L. McGuire, reported that material for construction of a table-top supersonic wind tunnel was being purchased.

▶ Captain L. W. Vincent, LSU AFROTC, discussed principles of flight and air-sea rescue work before 30 members at the October 3 meeting.

Captain Vincent concluded with a narrative of several air-sea rescue missions in which he participated while on duty in Europe.

DOUGLAS D. DUHON, *Secretary*

Massachusetts Institute of Technology

Raymond L. Bisplinghoff, Professor of Aeronautical Engineering, spoke on "Some Observations on the Aviation Industry in Western Europe" before 40 members and guests on October 15.

Professor Bisplinghoff, who taught in Europe during the past year, said emphasis in Great Britain is placed on de

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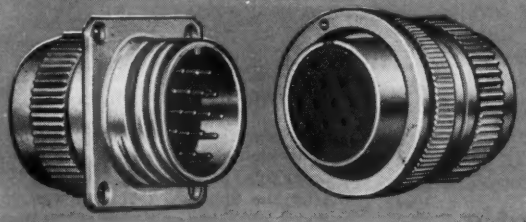

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fense with fighter aircraft and ground-to-air missiles. He said the Victory class bomber will be used until Great Britain can rely on the U.S. for ballistic missiles.

Britain's aviation industry will not suffer when fighters are abandoned because 40 per cent of its production is for export. Companies will undoubtedly specialize in missiles and transports, he said. Britain is advanced in engine development, but lags behind the United States in missile development.

He said that France produces little in quantity, but much in quality. Mach 2 fighter prototypes have been produced and the Caravelle appears to have a promising future. In Germany and Italy research is making renewed advances.

In Switzerland, where he taught, Professor Bisplinghoff said a Mach 1 ground support fighter is under development. Research, though not extensive, is carried on at the Swiss Federal Institute of Technology. Basic math and science courses are emphasized at this school and are probably superior to any in this country because of better precollege preparation. But, practical engineering lags resulting in students who have little grasp of industry requirements.

WILLIAM TOWLE, *Secretary*

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Lamb Electric ***fractional*** horsepower motors, like the small horses of the famed western-pioneer-day Pony Express, are developed for *stamina.*

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Radar voltage regulator gear motor.

. A rugged high-torque, high-speed motor.

Motor with efficient spur gear speed reducer.

U.S. Naval Postgraduate School

The initial business and organizational meeting of the Branch was held on September 26. It was well attended with more than half of those present being prospective new members.

New officers elected at this meeting were: Lt. Reese G. Belk, U.S. Navy, Chairman; Lt. Col. M. R. Yunck, U.S. Marine Corps, Vice-Chairman; Lt. Paul W. Utterback, U.S. Navy, Secretary-Treasurer; and Lt. Edwin L. Ebbert, U.S. Navy, Corresponding Secretary.

Richard M. Head, Professor of Aeronautics, will continue as Honorary Chairman and faculty advisor.

EDWIN L. EBBERT, *Corresponding Secretary*

University of Colorado

Some 65 members, mostly freshmen and sophomores, heard several short summer-work reports from students employed in the aircraft industry.

The meeting was concluded with a film on the Northrop Snark.

GARY E. COX, *Secretary*

University of Illinois

New officers elected at the first business meeting of the semester were Tom Martin, Chairman; Wallace Hanlon, Vice-Chairman; John Nedelk, Treasurer; Gary Grody, Secretary; and Harold Marthinsen, Engineering Council Representative.

Faculty Advisor Harry H. Hilton introduced E. J. Shockley of Lockheed Aircraft Corporation who spoke on flight-test engineering after the business meeting. Mr. Shockley is Division Engineer, Engineering Flight Test, Georgia Division.

He covered the various phases of flight test and showed a Lockheed film about C-130 modifications.

GARY G. GRODY, *Secretary*

University of Kentucky

The Challenge of Outer Space, a film starring Wernher von Braun, was shown at the October 31 meeting.

After the film new members were introduced and taken on a visit of the Wenner-Gren Aeronautical Research Laboratory.

A. L. WITTWER, *Secretary*

University of Minnesota

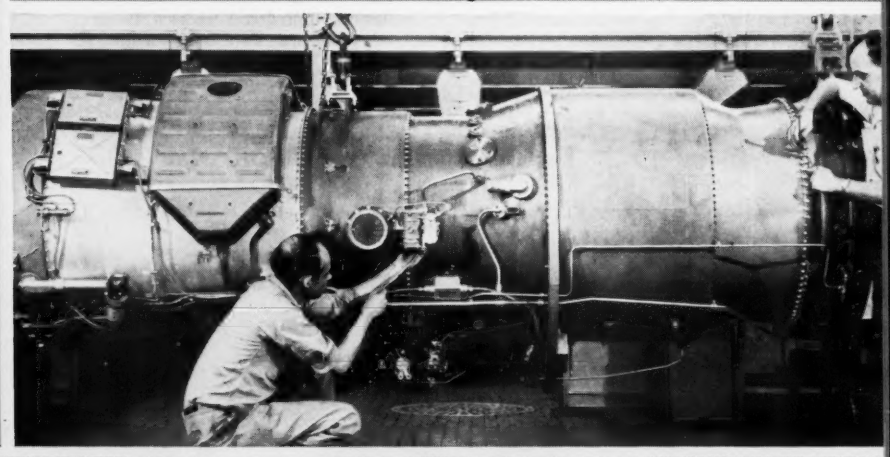
Helmut Heinrich, Visiting Professor at Minnesota, told how military and political requirements may initiate research work of permanent value, at the October 10 meeting.

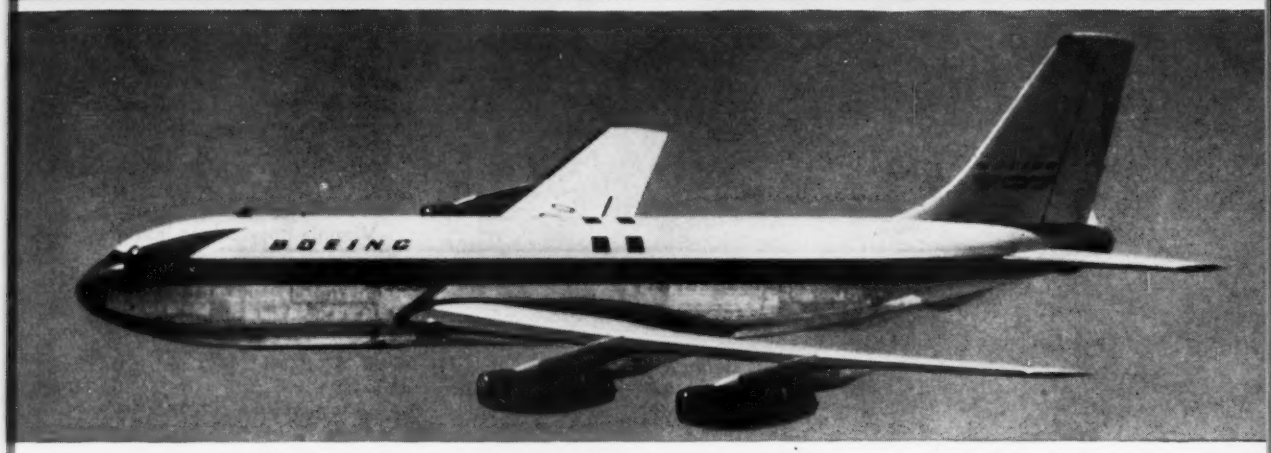
He drew from his wartime experience as Head, Research Institution Graf Zeppelin, Stuttgart, Germany, citing a study on controlled deceleration through hydraulic retardation under limited depth and surface condition. The Institution was asked to design a giant catapult for getting overloaded aircraft airborne. A subsequent design concept posed the

Holley engine controls selected for JT4 engines on America's first jet airliner

BLEED PISTON ACTUATOR

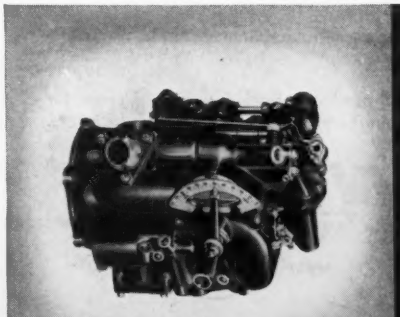
COMPRESSOR BLEED GOVERNOR





Powered by four JT4 Pratt & Whitney Aircraft engines, the Boeing 707-320 will carry 131 first class passengers from New York non-stop to the Continent in just over six hours! Each of these new engines, commercial counterparts to the J-75 which drives many of America's latest jet fighters, delivers up to 15,000 pounds of thrust. Ability to pack so much added power into a relatively small space is the result of designing engine components which will operate at higher efficiency, require less area and reduce over-all weight.

Holley Carburetor Company, working closely with Pratt & Whitney Aircraft engineers, carried out this exacting assignment on such vital engine components as: the compressor bleed governor, and the bleed governor actuator. For single and multi-engine military aircraft, the Holley main fuel control is a companion unit to the Holley governor and actuator.



For military applications, the Holley main fuel control (right) is a companion unit to the governor and actuator.

HOLLEY Carburetor Co.

11955 E. Nine Mile Road Warren, Michigan

Leader in the Design, Development and Manufacture of Aviation Fuel Metering Devices

requirement for a simple, reliable, and foolproof deceleration device which could absorb 1.61×10^8 ft.lb. of kinetic energy.

By combining knowledge of conventional shock absorbers and the theory of impact in unlimited water, a new device which operates between both extremes was devised. An analytical method for calculating the essential parts of the device was developed using test models.

Numerous laboratory experiments with models and a 6-ton capacity functioning catapult showed that bodies which fell freely from 50 ft. could be decelerated within 4 in. Deceleration during this period was nearly constant and ranged from 1 to 150 g's. The method worked for weights from 70 to 28,000 lbs., at impact speeds from 40 ft. per sec. to 60 ft. per sec., and for characteristic diameters from 0.9 to 9.8 ft.

DONNA R. HUBBARD, *Secretary*

University of Pittsburgh

The election of new officers highlighted the October 3 meeting. They are: Sandy A. Insana, Chairman; James Faherty, Vice-Chairman; James Hall, Corresponding Secretary; Robert F. Gusky, Recording Secretary and Treasurer; and Robert Doerzbacher, Program Chairman.

Members approved a motion to elect remaining officers at the next meeting at which time new Branch members would be eligible candidates.

ROBERT F. GUSKY, *Secretary*

University of Texas

A meeting on September 30 to acquaint freshmen with the IAS and its function resulted in 41 new members being accepted. Later, the new members were introduced to newly elected officers.

These are Paul Greer, Chairman; Earl Good, Vice-Chairman; Bill Campbell, Recording Secretary; Harold Malone, Corresponding Secretary; and Maxie Jarrell, Treasurer.

Each new officer discussed some phase of Branch activity covering programs scheduled, the Power Show, the Engineers' Ball and other social events.

VERNON H. MALONE, JR.,
Corresponding Secretary

University of Tulsa

E. W. Robischon, IAS Western Region Manager, spoke on "Shape of the Aircraft Industry Today—Where Do We Go From Here?" at the October 24 meeting. Mr. Robischon also showed a film, *Four Figured Flight*, of the Fairey Delta world-speed record.

▶ Chairman, Allen White, welcomed 26 new members who heard Allan McCaskill of Douglas Aircraft Company give a short talk at the October 17 meeting.

A film *Nike for the Defense of America* depicted the history and development of this missile with actual destruction of a target drone.

KENNETH L. ROGER, *Secretary*

Virginia Polytechnic Institute

Suggestions on future programs and activities for the school year were made by members at the first business meeting of the Branch on October 22.

Plans for a field trip to NACA Langley Laboratory and field trips to aircraft plants after Christmas also were discussed.

▶ *The Challenge of Outer Space* was seen by 220 members at the first meeting of the year in September. In the film Wernher von Braun, Director, Guided Missile Division, Redstone Arsenal, discusses problems of outer space travel with several officers of the Armed Forces Staff College.

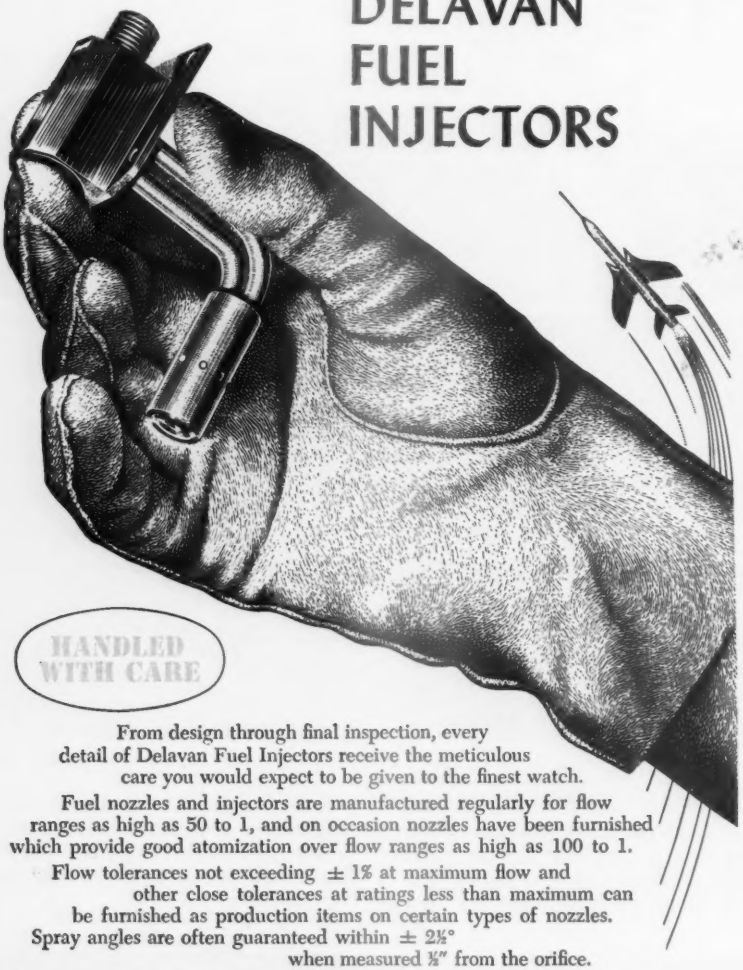
JAMES T. MCDANIEL, *Secretary*

✦ ✦ ✦

Attention Members!

All members of the Institute are invited to submit material concerning their activities for publication in the "News" columns of the *Aeronautical Engineering Review*.

DELAVAN FUEL INJECTORS



From design through final inspection, every detail of Delavan Fuel Injectors receive the meticulous care you would expect to be given to the finest watch.

Fuel nozzles and injectors are manufactured regularly for flow ranges as high as 50 to 1, and on occasion nozzles have been furnished which provide good atomization over flow ranges as high as 100 to 1.

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Aeronautical Reviews

A Guide to the Current Literature of Aeronautical Research and Engineering

THIS SECTION reviews important periodicals, technical and research reports, and books received in the IAS Library in order to provide basic documentation for engineers and scientists.

INTERNATIONAL AERONAUTICAL ABSTRACTS, published as an insert in each issue, is an accelerated reviewing service covering worldwide scientific and technical literature. This work is performed by the IAS Staff and is supported by the Air Force Office of Scientific Research of the Air Research and Development Command.

A list of the periodicals and reports series received in the IAS Library is published semiannually, in the January and July issues.

The AERONAUTICAL ENGINEERING INDEX, published since 1947, provides an annual cumulation of the materials reviewed in this section.

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The publications listed below represent periodicals currently received in the IAS Library for abstracting in the Aeronautical Reviews Section, including International Aeronautical Abstracts. Information includes the publisher's address, the frequency of publication, and, in most cases, the annual subscription cost to recipients in the United States. The frequency of publication is indicated as follows: BM, bimonthly; BW, biweekly; Irreg., irregularly; M, monthly; Q, quarterly; SA, semiannually; W, weekly.

These periodicals are maintained in the IAS Library and are made available through its lending, photocopy, and reference facilities. The IAS Library does not sell these publications.

Acad. Pol. Sci. Bul. Académie Polonaise des Sciences, Bulletin, Sniadeckich 8, Warsaw 10, Poland, Irreg.

Acta Metallurgica, 122 E. 55th St., New York 22, N.Y., M, $16

Acta Polytechnica. Royal Swedish Academy of Engineering Sciences, Stockholm, Sweden, Irreg.

Aerial. Marconi's Wireless Telegraph, Chelmsford, Essex, Eng., Q

Aero, Herman Lingg Strasse 9, Munich 15, Germany, M, DM 12

Aero Dig. Aero Digest, 14th & F Streets, NW, Washington 4, D.C., M, $5

Aero Eng. Aeronautical Engineering. Japan Society of Aeronautical Engineering, Hikokan No. 3, 1-chome, Shiba-tamura-cho, Minato-ku, Tokyo, Japan, M

Aero. Eng. Rev. Aeronautical Engineering Review. Institute of the Aeronautical Sciences, Inc., 2 E. 64 St., New York 21, N.Y., M, $3

Aéro France. Aéro Club de France, 6, rue Galilée, Paris 16, France, M, 1,200 fr.

Aero Mag. Aero Magazine (Supplement to Velocidade), Caixa Postal 4917, São Paulo, Brazil, M, Cr$200 (2 years)

Aero. Purchasing. Aeronautical Purchasing, 812 Huron Road, Cleveland 15, Ohio, M, $6

Aero. Quart. Aeronautical Quarterly. Royal Aeronautical Society, 4 Hamilton Place, London W 1, England, Q, $8.55

Aero Res. TN. Aero Research Technical Notes. Aero Research Ltd., Duxford, Cambridge, England, M

Aero. Soc. of India J. Aeronautical Society of India, Journal, New Delhi, India, Q, $2

Aeronautics, Tower House, Southampton St., Strand, London WC 2, England, M, 33s.

Aéronaves, Edificio Zingg, Caracas, Venezuela, BM

The Aeroplane, Bowling Green Lane, London EC 1, England, W, $14

Aeroporika Nea, 4 Othonos St., Athens, Greece, M

L'Aerotecnica. Associazione Italiana di Aerotecnica, Piazza S. Bernardo 101, Rome, Italy, M, L.3,000

Aerovox Res. Worker. Aerovox Research Worker. Aerovox Corp., New Bedford, Mass., M

Les Ailes, 77, blvd. Malesherbes, Paris 8, France, W, 1,200 fr.

L'Air, 71 Champs-Elysées, Paris 8, France, M, 1,500 fr.

Air Age, Mehta House, Apollo St., Bombay 1, India, BM, 12 rupees

Air BP. The British Petroleum Co., Ltd., Finsbury Circus, London, EC 2, England, Q

Air Facts, 30 Rockefeller Plaza, New York 20, N.Y., M, $3

Air Force. Air Force Assn., Mills Bldg., Washington 6, D.C., M, $4

Air Line Pilot, Air Line Pilots Assn., International, 55 St. & Cicero Ave., Chicago 38, Ill., M, $2.50

Air Pictorial. Air Pictorial and Air Reserve Gazette. Air League of the British Empire, Londonderry House, 19 Park Lane, London W 1, England, M, £1

Air Rev. Air Revue, 11 rue de Crayer, Brussels, Belgium, M, 350 fr. belge

Air Safety Dig. Air Safety Digest. Flight Safety Foundation, 468 4th Ave., New York 16, N.Y., Q

Air Transp. Air Transportation, 10 Bridge St., New York 4, N.Y., M, $5

Air U. Quart. Rev. Air University Quarterly Review, Maxwell AFB, Ala., Q, $2

Aircraft (Australia). Royal Aeronautical Society, Australian Division, etc., 26 Flinders St., Melbourne, Australia, M, 30s.

Aircraft (Canada), 341 Church St., Toronto 2, M, $5

Aircraft Eng. Aircraft Engineering, 12 Bloomsbury Sq., London WC 1, England, M, 40s.

Aircraft Heating Dig. Aircraft Heating Digest. Janitrol Aircraft-Automotive Division, Surface Combustion Corp., Columbus 16, Ohio, Irreg.

Aircraft Prod. Aircraft Production, Dorset House, Stamford St., London SE 1, England, M, $6

Airplane Patent Dig. Airplane Patent Digest. Manufacturers Aircraft Assn., Inc., 45 Rockefeller Plaza, New York 20, N.Y., SM

Airports & Air Transp. (see Airports & Airport Eng.)

Airports & Airport Eng. Airports & Airport Engineering, 92 Victoria St., London, SW 1, England, BM, 15s.

Allis-Chalmers Elec. Rev. Allis-Chalmers Electrical Review. Allis-Chalmers Mfg. Co., Milwaukee, Wis., Q, $2

AHS J. American Helicopter Society, Journal, 2 E. 64 St., New York 21, N.Y., Q, $4

AHS Newsletter. American Helicopter Society, Newsletter, 2 E. 64 St., New York, 21 N.Y., M, $3

Am. Av. American Aviation, 1001 Vermont Ave., NW, Washington 5, D.C., SM, $5

Am. Av. Daily (see **Av. Daily**)

Am. Ceram. Soc. Bul. American Ceramic Society, Bulletin, 4055 North High St., Columbus 14, Ohio, M, $6

Am. Ceram. Soc. J. American Ceramic Society, Journal (incl. **Ceramic Abstracts**), 4055 North High St., Columbus 14, Ohio, M, $14

Am. Engr. American Engineer. National Society of Professional Engineers, 2029 K St., NW, Washington 6, D.C., M, $3

Am. Helicopter. American Helicopter, 32 E. 57 St., New York 22, N.Y., M, $3.50

AMS Bul. American Meteorological Society, Bulletin, 3 Joy St., Boston 8, Mass., 10 issues per year, $8

AN SSSR Dokl. Akademiia Nauk SSSR, Doklady, Moscow, U.S.S.R., 36 issues per year

AN SSSR Mat. Inst. Trudy. Akademiia Nauk SSSR, Matematicheskii Institut, Trudy, Moscow, U.S.S.R., Irreg.

AN SSSR Otd. Tekh. Nauk Izv. Akademiia Nauk SSSR, Otdelenie Tekhnicheskikh Nauk, Izvestiia, Moscow, U.S.S.R., M

AN SSSR Vestn. Akademiia nauk SSSR, Vestnik, Moscow, M

Anal. Chem. Analytical Chemistry. American Chemical Society, 1155 16th St. NW, Washington 6, D.C., M, $4.50

Annals Phys. Annals of Physics, 111 5th Ave., New York 3, N.Y., M, $22

Appl. Hydraulics. Applied Hydraulics, 1240 Ontario St., Cleveland 13, Ohio, M, $5

Appl. Mech. Rev. Applied Mechanics Reviews. Southwest Research Institute, 8500 Culebra Rd., San Antonio 6, Tex., M, $25

Appl. Sci. Res., Sect. A. Applied Scientific Research, Section A, 9 Lange Voorhout, The Hague, Netherlands, Irreg., 21.50 guilder

Appl. Sci. Res., Sect. B. Applied Scientific Research, Section B, 9 Lange Voorhout, The Hague, Netherlands, Irreg., 21.50 guilder

Approach. U.S. Naval Aviation Safety Center. Supt. of Documents, Washington 25, D.C., M, $2.50

Arch. Budowy Maszyn. Archiwum Budowy Maszyn. Polska Akademia Nauk, ul. Nowy Swiat 72, Warsaw, Poland, Q, 80 zl.

Arch. Mech. Stosowanej. Archiwum Mechaniki Stosowanej. Polska Akademia Nauk, ul. Nowy Swiat 72, Warsaw, Poland, Q, 100 zl.

Argentina Aérea, Moreno 360, Buenos Aires, Argentina, M, $3

Arma Eng. Arma Engineering. Arma Div., American Bosch Arma Corp., Roosevelt Field, Garden City, N.Y., BM

ASA J. Acoustical Society of America, Journal, 334 E. 45th St., New York 17, N.Y., M, $14

ASEA Journal. ASEA, Västerås, Sweden, M

ASME Trans. American Society of Mechanical Engineers, Transactions, 29 W. 39 St., New York 18, N.Y., 8 issues per year, $12

Asoc. Argent. Interplan. Rev. Asociación Argentina Interplanetaria, Revista, Viamonte 867, Buenos Aires, Argentina, Q

Assoc. Comp. Mach. J. Association for Computing Machinery, Journal, 2 E. 63rd St., New York 21, N.Y., Q, $10

ASTM Bul. American Society for Testing Materials, Bulletin, 1916 Race St., Phila. 3, Pa., 8 issues per year, $2.75

Astronautica Acta, Molkerbastei 5, Vienna 1, Austria; I. R. Maxwell & Co., Ltd., London, Paris, New York, Q, $8.60

Astronautics. American Rocket Society, 500 5th Ave., New York 36, N.Y., M, $9

Auster News. Auster Aircraft Ltd., Rearsby Aerodrome, Leicester, Eng., Q

Australian J. Appl. Sci. Australian Journal of Applied Science. Commonwealth Scientific & Industrial Research Organization, 314 Albert St., East Melbourne C.2, Victoria, Australia, Q, £2

Australian J. Phys. Australian Journal of Physics. Commonwealth Scientific and Industrial Research Organization, 314 Albert St., East Melbourne C.2., Australia, Q, 30s.

Auto. Control. Automatic Control, 430 Park Ave., New York 22, N.Y., M, $10

Auto. Ind. Automotive Industries, Chestnut & 56 Sts., Phila. 39, Pa., SM, $2

Av. Age. Aviation Age, 205 E. 42 St., New York 17, N.Y., M, $10

Av. Daily. Aviation Daily, 1001 Vermont Ave., N.W., Washington 5, D.C., Daily, $200

Av. Mech. Bul. Aviation Mechanics Bulletin. Flight Safety Foundation, Inc., 468 Fourth Ave., New York 16, N.Y., BM, $1.20

Av. Res. & Devel. (see **Missile Des. & Devel.**)

Av. Week. Aviation Week, 330 W. 42 St., New York 36, N.Y., W, $6

Avia Vliegwereld. Royal Aero Club of the Netherlands, Anna Paulownaplein 3, The Hague, Netherlands, BW, 11 fl.

Aviação, Rua Uruguaiana 104-4, Rio de Janeiro, Brazil, M, Cr$600

Aviation Week Market Letter, 330 W. 42 St., New York 36, N.Y., M

Avión. Reál Aéro Club de España, Carrera de San Jerónimo 19, Madrid, Spain, M, 250 pesetas

Avtom. i Telemekh. Avtomatika i Telemekhanika. Institut Avtomatiki i Teemekhaniki, Otdelenie Tekhnicheskikh Nauk, Akademiia Nauk SSSR, Moscow, U.S.S.R., M

Battelle Tech. Rev. Battelle Technical Review. Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio, M

Bearing Engr. Bearing Engineer. The Torrington Company, 444 Madison Ave., New York 22, N.Y., Irreg.

Bee Hive, United Aircraft Corp., East Hartford, Conn., Q

Bell System Tech. J. Bell System Technical Journal. American Telephone and Telegraph Co., 195 Broadway, New York 7, N.Y., BM, $3

BOAC Review. British Overseas Airways Corp., Stratton House, Piccadilly, London W 1, England, M

Boeing Mag. Boeing Magazine. Boeing Airplane Co., 7755 E. Marginal Way, Seattle, Wash., M

Bristol Quart. The Bristol Quarterly. Bristol Aeroplane Company, Ltd., Filton House, Bristol, England, Q

Brit. Aircraft Ind. Bul. British Aircraft Industry Bulletin. Society of British Aircraft Constructors, 29 King St., St. James, London SW 1, England, Q

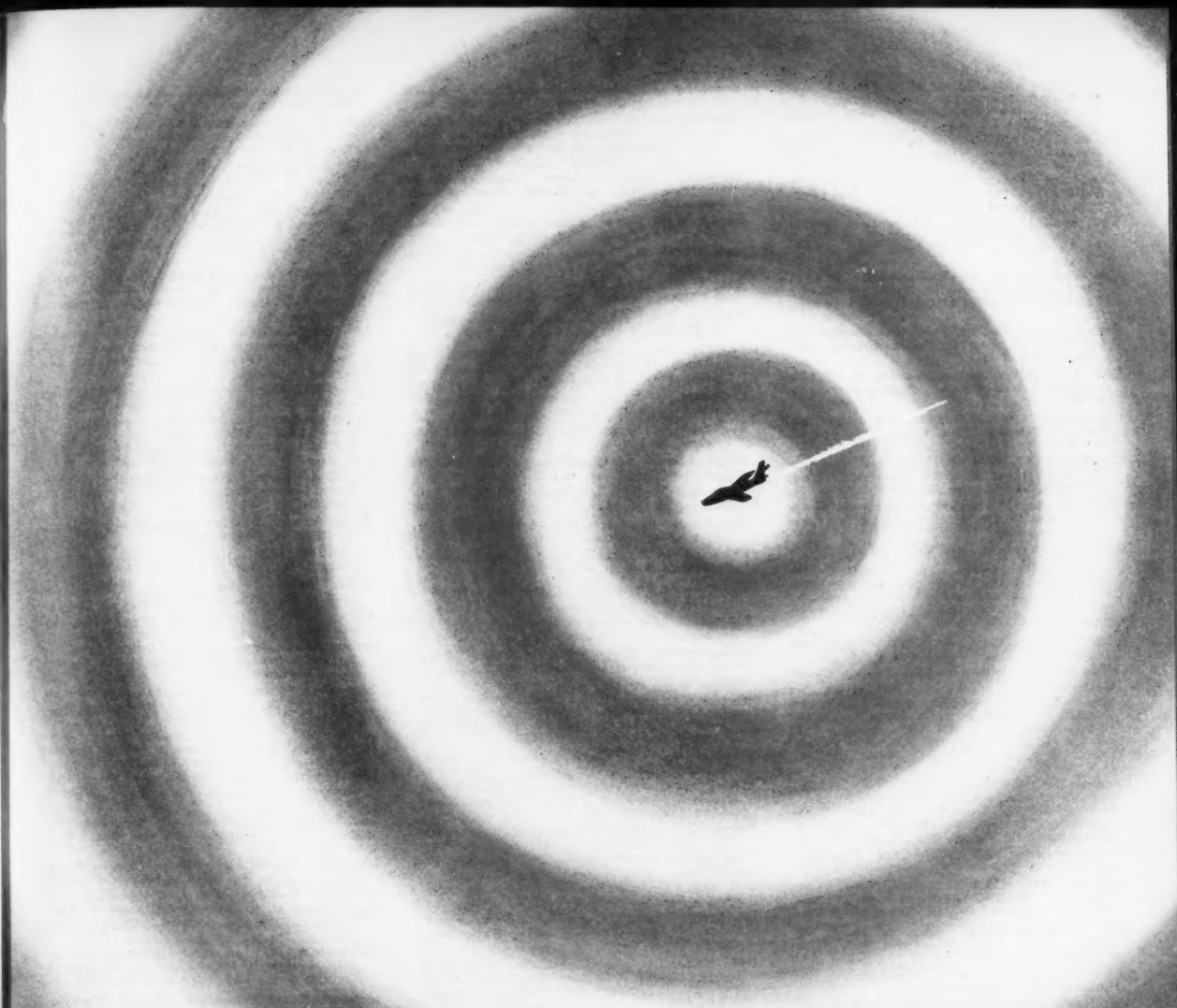
Brit. Interpl. Soc. J. British Interplanetary Society, Journal, 12 Bessborough Gardens, London SW 1, England, BM, 24s.

Brit. J. Appl. Phys. British Journal of Applied Physics. Institute of Physics, 47 Belgrave Sq., London SW 1, England, M, $11.50

Brit. Welding J. British Welding Journal. Institute of Welding, 2 Buckingham Gardens, London, SW 1, England, M, £5

Brown Boveri Rev. Brown Boveri Review. Brown, Boveri & Co., Ltd., Baden, Switzerland, M

Bul. Liais. Doc. Bulletin de Liaison et de Documentation du Secrétariat Général à l'Aviation Civile et Commerciale, 93 blvd. du Montparnasse, Paris 6, France, BM



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Bul. Stiint. Sect. Stiinte Mat. Fiz. Bulletin Stiintific, Sectiunea de Stiinte Matematice si Fizice, Academia Republicii Populare Romine, Bucarest, Rumania, Q

BWK. Brennstoff-Wärme-Kraft. VDI-Verlag, Bongardstrasse 3, Düsseldorf, Germany, M, DM 52

Cambridge Philos. Soc. Proc. Cambridge Philosophical Society, Proceedings, Free School Lane, Cambridge, England, Q, £5

Can. Aero. J. Canadian Aeronautical Journal. Canadian Aeronautical Institute, Commonwealth Building, 77 Metcalfe St., Ottawa, Canada, M, $4

Can. Airline Pilot. The Canadian Airline Pilot. The Canadian Airline Pilots Assn., 400 Electric Railway Chambers, Winnipeg, Manitoba, Canada, Q

Can. Flight. Canadian Flight, Canadian Owners & Pilots Assn., Box 734, Sta. B, Ottawa, Ont., Canada, BM, $4

Can. J. Phys. Canadian Journal of Physics. National Research Council, Ottawa 2, Canada, M, $4

Can. J. Tech. Canadian Journal of Technology. National Research Council, Ottawa 2, Canada, BM, $3

Canada, NAE Quart. Bul. Canada, National Aeronautical Establishment, Quarterly Bulletin, Montreal Road, Ottawa, Canada, Q

CEC Recordings. Consolidated Electrodynamics Corp., 300 North Sierra Madre Villa, Pasadena, Calif., BM

Ceramic Abstracts (see **Am. Ceram. Soc. J.**)

Chartered Mech. Engr. The Chartered Mechanical Engineer; The Journal of the Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London SW 1, England, 10 issues per year, £2. 5s. 6d.

Cienc. Aero. Ciencia Aeronáutica, Apartado de Correos 3879, Caracas, Venezuela, M, $4

Collins Signal. Collins Radio Company, Cedar Rapids, Iowa, Q

Comb. & Flame. Combustion and Flame. The Combustion Institute. Butterworths Scientific Publications, 4-5 Bell Yard, Temple Bar, London, WC 2, England; Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N.Y., Q, £5, 5s., $16

Commun. on Pure & Appl. Math. Communications on Pure and Applied Mathematics. Institute of Mathematical Sciences, New York University. Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N.Y., Q, $8

Connecting Link. Link Aviation, Inc., Binghamton, N.Y., Irreg.

Cook Tech. Rev. Cook Technical Review, Cook Electric Co., 2700 N. Southport Ave., Chicago 14, Ill., Irreg.

Data Processing Digest. Canning, Sisson, & Associates, 914 South Robertson Blvd., Los Angeles 35, Calif., M, $24

de Havilland Gazette. de Havilland Enterprise Hatfield, Herts, England, Q

Des. News. Design News, 3375 S. Bannock, Englewood, Colo., SM, $20

Docaéro. Service de Documentation et d'Information Technique de l'Aéronautique (SDIT), 2, avenue de la Porte d'Issy, Paris 15, France, BM

Douglas Serv. Douglas Service. Douglas Aircraft Co., Inc., 3000 Ocean Park Blvd., Santa Monica, Calif., BM

Elec. Commun. Electrical Communication. International Telephone and Telegraph Corp., 67 Broad St., New York 4, N.Y., Q, $2

Elec. Energy. Electrical Energy, 28 Essex St., Strand, London WC 2, England, M, $5

Elec. Eng. Electrical Engineering. American Institute of Electrical Engineers, 33 W. 39 St., New York 18, N.Y., M, $12

Elec. Mfg. Electrical Manufacturing, 1250 6th Ave., New York 20, N.Y., M

Electronic & Radio Eng. Electronic & Radio Engineer, incorporating Wireless Engineer, Dorset House, Stamford St., London SE 1, England, M, $7.50

Electronic Appl. Rel. Rev. Electronic Applications Reliability Review. Radio-Electronics-Television Manufacturers Assn., 500 Fifth Ave., New York 36, N.Y., Irreg.

Electronic Des. Electronic Design, 19 E. 62 St., New York 21, N.Y., M

Electronic Eng. Electronic Engineering, 28 Essex St., Strand, London WC 2, England, M, $4

Electronic Ind. & Tele-Tech. Electronic Industries & Tele-Tech., 480 Lexington Ave., New York 17, N.Y., M, $5

Electronics, 330 W. 42 St., New York 36, N.Y., M, $6

Energetica si Hidrotehnica, str. Ioan Ghica 3, Bucarest, Rumania, M, lei 30

Eng. J. Engineering Journal. Engineering Institute of Canada, 2050 Mansfield St., Montreal, Canada, M, $6

The Engr. The Engineer, 28 Essex St., London WC 2, England, W, £5

Engr. Dig. The Engineers' Digest, 120 Wigmore St., London W1, England, M, $7.50

Environmental Quart. Environmental Quarterly. Institute of Environmental Engineers, Inc., and Environmental Equipment Institute, Inc., 9 Spring St., Princeton, N.J., Q, $4

Ericsson Tech. Ericsson Technics. Telefonaktiebolaget L.M. Ericsson, Stockholm 32, Sweden, SA

Escher Wyss News. Escher Wyss Engineering Works Ltd., Zurich, Switzerland, Irreg.

Esso Air World. Esso Export Corp., 60 W. 49 St., New York 20, N.Y., BM

Esso Aviation News Digest. Esso Export Corp., 45 Rockefeller Plaza, New York 21, N.Y., W

FAI Bul. Fedération Aéronautique Internationale, Bulletin, 6, rue Galilée, Paris, France, Q

FAI Circ. Inf. Fedération Aéronautique Internationale, Circulaire d'Information, 6, rue Galilée, Paris, France, Irreg.

Fasteners. Industrial Fasteners Institute, 1517 Terminal Tower, Cleveland 13, Ohio, Q

Flight, Dorset House, Stamford St., London SE 1, England, W, $14

Flight Control. Eclipse-Pioneer Div., Bendix Aviation Corp., Teterboro, N.J., M

Flight Mag. Flight Magazine, 2700 N. Haskell, Dallas, Tex., M, $3

Flug-Revue, Paulinenstrasse 44, Stuttgart, Germany, M, DM 25.20

Flugwehr und -Technik, 16 Promenadenstrasse Frauenfeld, Switzerland, M, 13 Sw. fr.

Flugwelt, Bahnhofstr. 61, Wiesbaden, Germany, M, DM 21.60

Flying, 366 Madison Ave., New York 17, N.Y., M, $4

Flying Safety. USAF Office of Flying Safety. Superintendent of Documents, Washington 25, D.C., M, $3

Forschung Gebiete Ing., Ausg. A. Forschung auf dem Gebiete des Ingenieurwesens, Ausgabe A. Verein deutscher Ingenieure, Bongardstr. 3, Düsseldorf, Germany, BM, DM 51

Franklin Inst. J. Franklin Institute, Journal, Parkway at 20 St., Phila. 3, Pa., M, $10

The Frontier. Armour Research Foundation, Illinois Institute of Technology, Technology Center, Chicago 16, Ill., Q

Fusées et Recherche Aéronautique. Association pour l'Encouragement à la Recherche Aéronautique, 1 rue de Courty, Paris 7, France, Q. 5,500 fr.

G-E Rev. General Electric Review. General Electric Co., Schenectady 5, N.Y., BM

Gen. Radio Exper. General Radio Experimenter General Radio Company, 275 Mass. Ave., Cambridge 39, Mass., M

GM Eng. J. General Motors Engineering Journal. General Motors Technical Center, P.O. Box 177, North End Station, Detroit 2, Mich., BM

Grazhdanskaia Aviatsiia. Glavnoe Upravlenie Grazhdanskogo Vozdushnogo Flota, Moscow, U.S.S.R., M

Guild J. Guild Journal. The Guild of Air Pilots and Air Navigators of the British Empire, 19 Park Lane, London W 1, England, Q

Handley-Page Bul. Handley-Page Bulletin. Handley-Page Ltd., London NW 2, England, Q

Hawker Siddeley Rev. Hawker Siddeley Review. Hawker Siddeley Group Ltd., 18 St. James's Square, London, SW 1, England, Q

Helicopter Assn. Gt. Brit. J. Helicopter Assn. of Gt. Britain, Journal, 4, The Sanctuary, Westminster, London SW 1, England, Q

Hokkaidô Gakugei U. J. Sect. B. Hokkaidô Gakugei University, Journal, Section B, Sapporo, Japan, Q

Honeywell Flight Lines. Aeronautical Division, Minneapolis-Honeywell Regulator Co., 2600 Ridgeway Road, Minneapolis 13, Minn., BM

Hosei U. Tech. Coll. Rep. Hosei University, Technical College, Reports, 7 Sinbouryo, Azabu, Minato-ku, Tokyo, Japan, Irreg.

Hunting Group Rev. Hunting Group Review, 4 Dunraven St., Park Lane, London W 1, England, Q

Hydraulic Engr. Hydraulic Engineer. Electrol Inc., 85 Grand St., Kingston, N.Y., BM

IATA Bul. IATA Bulletin. International Air Transport Assn., International Aviation Bldg., 1080 University St., Montreal 3, Canada, SA, $3.75

IBM J. Res. & Devel. IBM Journal of Research and Development. International Business Machines Corp., 590 Madison Ave., New York 22, N.Y., Q, $3.50

ICAO Bul. ICAO Bulletin. International Civil Aviation Organization, International Aviation Bldg., 1080 University St., Montreal 3, Canada, M, $2

IEE Proc. B. Institution of Electrical Engineers, Proceedings, Part B, Savoy Place, London WC 2, England, BM, £2 5s.

Ilmailu, Mannerheimintie 16-A, Helsinki, Finland, M, Fmk. 600

IME Proc. Institution of Mechanical Engineers, Proceedings, 1 Birdcage Walk, Westminster, London SW 1, England, Irreg.

Ind. & Eng. Chem. Industrial and Engineering Chemistry. American Chemical Society, 1155 16th St., NW, Washington 6, D.C., M, $4.50

Ind. Aeronautics. Industrial Aeronautics, 31–35 Willcocks St., Montreal, P.Q., Canada, M, $5

Ind. Labs. Industrial Laboratories, 201 N. Wells St., Chicago 6, Ill., M

Ind. Quality Control. Industrial Quality Control. American Society for Quality Control, Inc., Room 6197, 161 W. Wisconsin Ave., Milwaukee 3, Wis., M, $9

Ind. Res. Newsletter. Industrial Research Newsletter. Armour Research Foundation, Illinois Institute of Technology, Technology Center, Chicago 16, Ill., M

Ind. Sci. & Eng. Industrial Science and Engineering, 201 N. Wells St., Chicago 6, Ill., BM

Index Aeronauticus. Ministry of Supply, Leysdown Road, Mottingham, London, SE 9, England; British Joint Services Mission, 1800 K St., N.W., Washington, D.C., M

Indian AF Quart. Indian Air Force Quarterly. Directorate of Training, Air HQ, New Delhi, India, Q

Indian Airman, Roy Mansions, Behala, Calcutta 34, India, M, 10 Rupees

Indian Inst. Sci. J. Indian Institute of Science, Journal, Bangalore 3, India, M, $6.50

Indian Skyways, Gandhigram Road, Juhu, Bombay 23, India, M, 20 Rupees

Info. & Control. Information and Control, 111 5th Ave., New York 3, N.Y., Q, $10

Informations Aéronautiques. Union Syndicale des Industries Aéronautiques, 4 rue Galilée, Paris 16, France, W

Ing. Aeronáutica. Ingeniería Aeronáutica. Asociación de Ingenieros Aeronáuticos, Arcipreste de Hita 14, Madrid, Spain, BM, 200 pesetas

Ing.-Arch. Ingenieur-Archiv. Neuenheimer Landstr. 24, Heidelberg, Germany, BM

Inst. Electronics Proc. Institute of Electronics, Proceedings, 5 Baron Place, London SE 1, England, Irreg.

Inst. Navigation J. Institute of Navigation, Journal, 1 Kensington Gore, London SW 7, England, Q, $6

Inst. Roy. Météor. Belg. Bul. Institut Royal Météorologique de Belgique, Bulletin, Uccle, Brabant, Belgium, Irreg.

Inst. Transp. J. Institute of Transport, Journal, 80 Portland Place, London W 1, England, BM, 21s.

Instrumentation. Industrial Division, Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Philadelphia 44, Pa., BM

Instruments and Automation, 1600 N. Main St., Pontiac, Ill., M, $4

Interavia, 6 Corraterie, Geneva, Switzerland, M, $7

IRE. Proc. Institute of Radio Engineers, Proceedings, 1 E. 79 St., New York 21, N.Y., M, $18

IRE Trans. Institute of Radio Engineers, Transactions, 2 E. 79th St., New York 21, N.Y.
- **ANE.** Aeronautical and Navigational Electronics, Q, $17
- **AP.** Antennas and Propagation, Q, $17
- **CS.** Communications Systems, Q, $17
- **EC.** Electronic Computers, Q, $17
- **TRC.** Telemetry & Remote Control, Q, $17

ISA J. Instrument Society of America, Journal, 1319 Allegheny Ave., Pittsburgh 33, Pa., M, $4

Istanbul Tek. U. Bul. Istanbul Teknik Üniversitesi, Bülteni, Istanbul, Turkey, Annually

Izmer. Tekh. Izmeritel'naia Tekhnika. Komitet Standartov, Mer i Izmeritel'nykh Priborov, Moscow, U.S.S.R., BM

J. Aero. Sci. Journal of the Aeronautical Sciences. Institute of the Aeronautical Sciences, Inc., 2 East 64th St., New York 21, N.Y., M, $15

J. Air Law & Commerce. Journal of Air Law & Commerce. Northwestern University, Chicago 11, Ill., Q, $6

J. Appl. Mech. Journal of Applied Mechanics. American Society of Mechnical Engineers, 29 W. 39 St., New York 18, N.Y., Q, $5

J. Appl. Phys. Journal of Applied Physics. American Institute of Physics, 57 E. 55 St., New York 22, N.Y., M, $12

J. Astronautics. Journal of Astronautics. American Astronautical Society, 516 Fifth Ave., New York 36, N.Y., Q, $6

J. Atmos. & Terrestrial Phys. Journal of Atmospheric and Terrestrial Physics, 4 Fitzroy Square, London W1, England; 122 E. 55th St., New York 22, N.Y., BM, $14

J. Av. Med. Journal of Aviation Medicine. Aero Medical Assn., 2642 University Ave., St. Paul 14, Minn., BM, $7.50

J. Eng. Educ. Journal of Engineering Education. American Society for Engineering Education, University of Illinois, Urbana, Ill., M, $6

J. Fluid Mech. Journal of Fluid Mechanics, Taylor & Francis Ltd., Red Lion Court, Fleet St., London EC 4, England; Academic Press, Inc., 111 5th Ave., New York 3, N.Y., BM, £3. 10s., $16.50

J. Math. & Mech. Journal of Mathematics & Mechanics. Graduate Institute for Applied Mathematics, University of Indiana, Bloomington, Ind., BM, $18

J. Math. & Phys. Journal of Mathematics and Physics. MIT, Cambridge 39, Mass., Q, $6

J. Mech. & Phys. Solids. Journal of the Mechanics and Physics of Solids, 4 Fitzroy Square, London W 1, England; 122 E. 55th St., New York 22, N.Y., Q, $12.60

J. Metals. Journal of Metals. American Institute of Mining, Metallurgical and Petroleum Engineers, 29 W. 39th St., New York 18, N.Y., M, $8

J. Meteorology. Journal of Meteorology. American Meteorological Society, 3 Joy St., Boston 8, Mass., BM, $9.50

J. Res. Journal of Research. U.S. National Bureau of Standards. Supt. of Documents, Washington 25, D.C., M, $4

J. Sci. & Ind. Res. Journal of Scientific & Industrial Research. Council of Scientific & Industrial Research, 20 Pusa Road, New Delhi 5, India, 15 Rupees

J. Sci. Instr. Journal of Scientific Instruments. Institute of Physics, 47 Belgrave Square, London SW 1, England, M, £5

J. Space Flight. Journal of Space Flight (including the Rocket Newsletter). Chicago Rocket Society, 948 119 St., Whiting, Ind., M. $6

J. Tech. Journal of Technology, Bengal Engineering College, Superintendent—Govt. Printing, Calcutta, India, SA, $2.50

Japan Sci. Rev. Mech. & Elec. Eng. The Japan Science Review, Mechanical & Electrical Engineering. Japan Society of Mechanical Engineers (with cooperation of allied engineering societies and associations), Maronouchi Bldg.. Chiyoda-Ku, Tokyo, Japan, SA, $2

Japan Soc. Aero. Eng. J. Japan Society of Aeronautical Engineering, Journal, Kikokwan No. 3, 1-chome, Shiba-Tamura-cho, Minato-ku, Tokyo, Japan, M

Jet Age. A. V. Roe, Ltd., P.O. Box 430, Toronto, Ontario, Canada, Q

Jet Propulsion. American Rocket Society, 500 Fifth Avenue, New York 36, N.Y., M, $12.50

Joint Services Recognition Journal. Air Ministry, Richmond Terrace. Whitehall, London SW 1, England, M

Kryl'ia Rodiny. DOSAAF, Novo-Rianzanskaia 26, Moscow, USSR, M

Kyushu U., Rep. Res. Inst. Appl. Mech. Kyushu University, Research Institute for Applied Mechanics, Reports, Fukuoka, Japan, SA

Light Metals, Bowling Green Lane, London EC 1, England, M, 26s.

Lockheed Field Serv. Dig. Lockheed Field Service Digest. Lockheed Aircraft Corp., Burbank, Calif., BM

The Log. British Air Line Pilots Assn., 95 Mount St., London W 1, England, M

Lond. Math. Soc. Proc. London Mathematical Society, Proceedings, Amen House, London EC 4, England, Q, £4

Lubrication. The Texas Co., 135 E. 42nd St., New York 17, N.Y., M

Lubrication Eng. Lubrication Engineering. American Society of Lubrication Engineers, 84 E. Randolph St., Chicago 1, Ill., M, $6

Luftfahrttechnik. Verein deutscher Ingenieure, Bongardstr. 3, Düsseldorf, Germany, M, DM 43.50

Mach. Des. Machine Design, Cleveland 13, Ohio, BW, $10

Mag. of Magnesium. Magazine of Magnesium. Brooks & Perkins, Inc., 1950 Fort St., Detroit 16, Mich., Q

Mag. of Standards. Magazine of Standards. American Standards Assn., Inc., 70 E. 45 St., New York 17, N.Y., M, $7

Marconi Rev. The Marconi Review. Marconi's Wireless Telegraph Co. Ltd., Chelmsford, England, Q

Materials & Methods (see next entry)

Materials in Des. Eng. Materials in Design Engineering, 430 Park Ave., New York 22, N.Y., M, $3

Math. Tables Aids to Comp. Mathematical Tables and Other Aids to Computation. National Academy of Sciences—National Research Council, 2101 Constitution Ave., Washington, D.C., Q, $5

MATS Flyer. Military Air Transport Service. Supt. of Documents, Washington 25, D.C., M, $2.25.

Mech. Eng. Mechanical Engineering. American Society of Mechanical Engineers, 29 W. 39 St., New York 18, N.Y., M, $7

Mechanika. Central Library, Polytechnic School, 155 Gdanska, Lodz, Poland, Irreg.

Metal Treat. Metal Treatment and Drop Forging, 17–19 John Adam St., Adelphi, London WC 2, England, M, 30s.

Metallurgia, 31 King St. W., Manchester 3, England, M, 24s.

Meteor. Abs. & Bibliog. Meteorological Abstracts and Bibliography. American Meteorological Society, 3 Joy St., Boston 8, Mass., M, $8

Meteorological Mag. The Meteorological Magazine. Air Ministry Meteorological Office. British Information Services, 45 Rockefeller Plaza, New York 20, N.Y., M, $4

Meteoros. Servicio Meteorológico Nacional, Buenos Aires, Argentina, Q, 40 pesos

Mil. Electronics. Military Electronics, 2775 S Moreland Blvd., Cleveland 20, Ohio, M, $9

Mil. Med. Military Medicine. Assn. of Military Surgeons, 1726 Eye Street, NW, Washington, D.C., M, $7.50

Military Aircraft Data Sheets. Aviation Studies (International) Ltd., 29–31 Cheval Place, Knightsbridge, London SW 7, England, Q, £2

Missiles & Rockets, 1001 Vermont Avenue, NW, Washington 5, D.C., M, $8

Missile Des. & Devel. Missile Design & Development, 140 E. 40th St., New York 16, N. Y., M, $10

Mo. Weather Rev. Monthly Weather Review. U.S. Weather Bureau. Supt. of Documents Washington 25, D.C., M, $3

Nav. Res. Logistics Quart. Naval Research Logistics Quarterly. Office of Naval Research. Superintendent of Documents Washington 25, D.C., Q, $1.50

Naval Av. News. Naval Aviation News. Chief of Naval Operations and Bureau of Aeronautics. Superintendent of Documents, Washington 25, D.C., M, $2

Navigation. Institut Français de Navigation, 13 rue de l'Université, Paris 7, France, Q, 2,500 fr.

Navigation. Institute of Navigation, University of California, 405 Hilgard Ave., Los Angeles 24, Calif., Q, $10

News Eng. News in Engineering. Engineering Experiment Station, Ohio State University, Columbus 10, Ohio, Q, $1

News Report, National Academy of Sciences. National Research Council, 2101 Constitution Ave., Washington 25, D.C., BM, $2

Noise Control. Acoustical Society of America, 57 East 55 St., New York 22, N.Y., BM, $8

Notiz. Av. Notiziario de Aviazione. Ufficio del Segretario Generale, Ministero della Difesa—Aeronautica, Rome, Italy, M

Novye Knigi. Ministerstvo Kul'tury SSSR, Moscow, W

Nuclear Eng. Nuclear Engineering, Bowling Green Lane, London EC 1, England, M, $7

Nucleonics, 330 W. 42nd St., New York 36, N.Y., M, $8

Official Air Line Guide, 1001 Vermont Ave., NW, Washington 5, D.C., M, $13.50

Oper. Res. Operations Research. Operations Research Society of America, Mt. Royal & Guilford Aves., Baltimore 2, Md., BM, $7.50

Ordnance. American Ordnance Assn., 708 Mills Bldg., Washington 6, D.C., BM, $4.50

OSA J. Optical Society of America, Journal, 334 E. 45th St., New York 17, N. Y., M, $8.50

Pacific J. Math. Pacific Journal of Mathematics. Univ. of California Press, Berkeley 4, Calif., Q, $12

Papers in Meteorology & Geophys. Papers in Meteorology and Geophysics. Meteorological Research Institute, Mabashi, Suginami, Tokyo, Japan, Irreg.

Pegasus. Fairchild Engine and Airplane Corp., Hagerstown, Md., M

Philips Tech. Rev. Philips Technical Review. N.V. Philips Co., Eindhoven, Netherlands, M, $5

Philos. Mag. The Philosophical Magazine, Red Lion Court, Fleet St., London EC 4, England, M, £8

Photogrammetric Eng. Photogrammetric Engineering, American Society of Photogrammetry, 1515 Massachusetts Ave., NW, Washington 5, D.C., 5 issues per year, $6

Photographic Eng. Photographic Engineering. Society of Photographic Engineers, Box 6077, Mid-City Sta., Washington 5, D.C., Q, $8

Phys. Soc. Japan J. Physical Society of Japan, Journal, Dept. of Physics, Faculty of Science, University of Tokyo, Bunkyo-ku, Tokyo, Japan, M, $5

Planes. Aircraft Industries Assn. of America, 610 Shoreham Bldg., Washington 5, D.C., M

Pol. Inst. Lot. Prace. Poland, Instytut Lotnictwa, Prace. Ministerstwo Przemysu Maszynowego, Warsaw, Poland, Irreg.

Prikl. Mat. i Mekh. Prikladnaia Matematika i Mekhanika, Akademiia Nauk SSSR, Moscow, USSR, BM

Prod. Eng. Product Engineering, 330 W. 42 St., New York 36, N.Y., W, $5

Project Engr. Project Engineer. The Thermix Corp., Greenwich, Conn., M

Propel, Mariagervej 4, Helsingor, Denmark, M

Protar, Solothurn, Switzerland, BM, 15 Sw. fr.

Quart. Appl. Math. Quarterly of Applied Mathematics. Brown University, Providence 12, R.I., Q, $6

Quart. J. Mech. & Appl. Math. Quarterly Journal of Mechanics and Applied Mathematics, Amen House, London EC 4, England, Q, 60s.

RCA Rev. RCA Review. RCA Laboratorie Radio Corporation of America, Princeton, N.J Q, $2

RAeS J. Royal Aeronautical Society, Journal, 4 Hamilton Place, London W 1, England, M, £ 10s. 6d.

Raketentech. & Raumfahrtforsch. Raketentechnik und Raumfahrtforschung. Deutsche Gesellschaft für Raketentechnik und Raumfahrt, Neuensteiner Strasse 19, Stuttgart-Zuffenhausen, Germany, Irreg., $1 per issue

Rec. Ocean. Works Japan. Records of Oceanographic Works in Japan. Japanese National Commission for UNESCO, 4-3 Kasumigasiki, Chiyoda-ku, Tokyo, Japan, Irreg.

La Recherche Aéronautique. Office National d'Etudes et de Recherches Aéronautiques (ONERA), 29 ave. de la Division-Leclerc, Chatillon-sous-Bagneux (Seine), France, BM, 4,300 fr.

Repülés, Engels tér 14, Budapest 5, Hungary, M, 48 ft.

Res. Rev. Research Reviews. Office of Naval Research, Department of the Navy. Supt. of Documents, Washington 25, D.C., M, $1.50

Res. Trends. Research Trends. Cornell Aeronautical Laboratory, Inc., 4455 Genessee St., Buffalo 21, N.Y., Q

Rev. Aero. Revista de Aeronáutica. Ministro del Aire, 8 Romero Robledo, Madrid, Spain, M, 90 pesetas

Rev. Math. Pures & Appl. Revue de Mathématiques Pures et Appliquées. Académie de la Republique Populaire Roumaine, 125, Calea Victoriei, Bucarest, Rumania, Irreg.

Rev. Méc. Appl. Revue de Méchanique Appliquée. Institut de Mécanique Appliquée, Académie de la Republique Populaire Roumaine, 15 rue C. Mille, Bucarest, Rumania, Irreg.

Rev. Nac. Aero. Revista Nacional de Aeronáutica, 741 Ave. Cordoba, Buenos Aires, Argentina, M, $6

Rev. Phys. Revue de Physique, Academia Republicii Populare Romine, Bucarest, Rumania, Irreg.

Rev. Sci. Instr. Review of Scientific Instruments. American Institute of Physics, 57 E. 55 St., New York 22, N.Y., M, $9

Rev. Sci. Tech. Revue des Sciences Techniques. Académie de la Republique Populaire Roumaine, 125, Calea Victoriei, Bucarest, Rumania, Irreg.

Rev. SNCASO. Revue SNCASO. Société Nationale de Constructions Aéronautiques du Sud-Ouest, avenue Raymond Poincaré 105, Paris 16, France, Q

Rev. Transp. Revista Transporturilor. Str. Ioan Ghica 3, Bucarest, Rumania, M, lei 30

Riv. Aero. Rivista Aeronautica. Ministero Difesa—Aeronautica, viale dell'Universitá 4, Rome, Italy, M, $7

Riv. Med. Aero. Rivista di Medicina Aeronautica, via P. Gobetti 2, Rome, Italy, Q, L. 3,600

Riv. Meteorologia Aero. Rivista di Meteorologia Aeronautica. Servizio Meteorologico d'Aeronautica, via San Vincenzo di Paoli 11, Rome, Italy, Q, L. 3,000

Royal Soc. Edin. Proc. A. Royal Society of Edinburgh, Proceedings, Section A, Mathematical and Physical Sciences, 22 George St., Edinburgh 2, Scotland, Irreg.

Royal Soc. (London) Philos. Trans. Ser. A. Royal Society (London), Philosophical Transactions, Series A, Mathematical and Physical Sciences, Burlington House, Piccadilly, London W 1, England, Irreg., £9 9s.

Royal Soc. (London) Proc. Ser. A. Royal Society (London), Proceedings, Series A, Mathematical and Physical Sciences, Burlington House, Piccadilly, London W 1, England, Irreg.

Rozprawy Inzynierskie. Polska Akademia Nauk, ul. Nowy Swiat 72, Warsaw, Poland, Q, 80 zl.

Ryan Reporter. Ryan Aeronautical Co., P.O. Box 311, San Diego 12, Calif.

Saab Sonics. Saab Aircraft Co., Linköping, Sweden, Irreg.

SAE J. Society of Automotive Engineers, Journal, 485 Lex. Ave., New York 17, N.Y., M, $10

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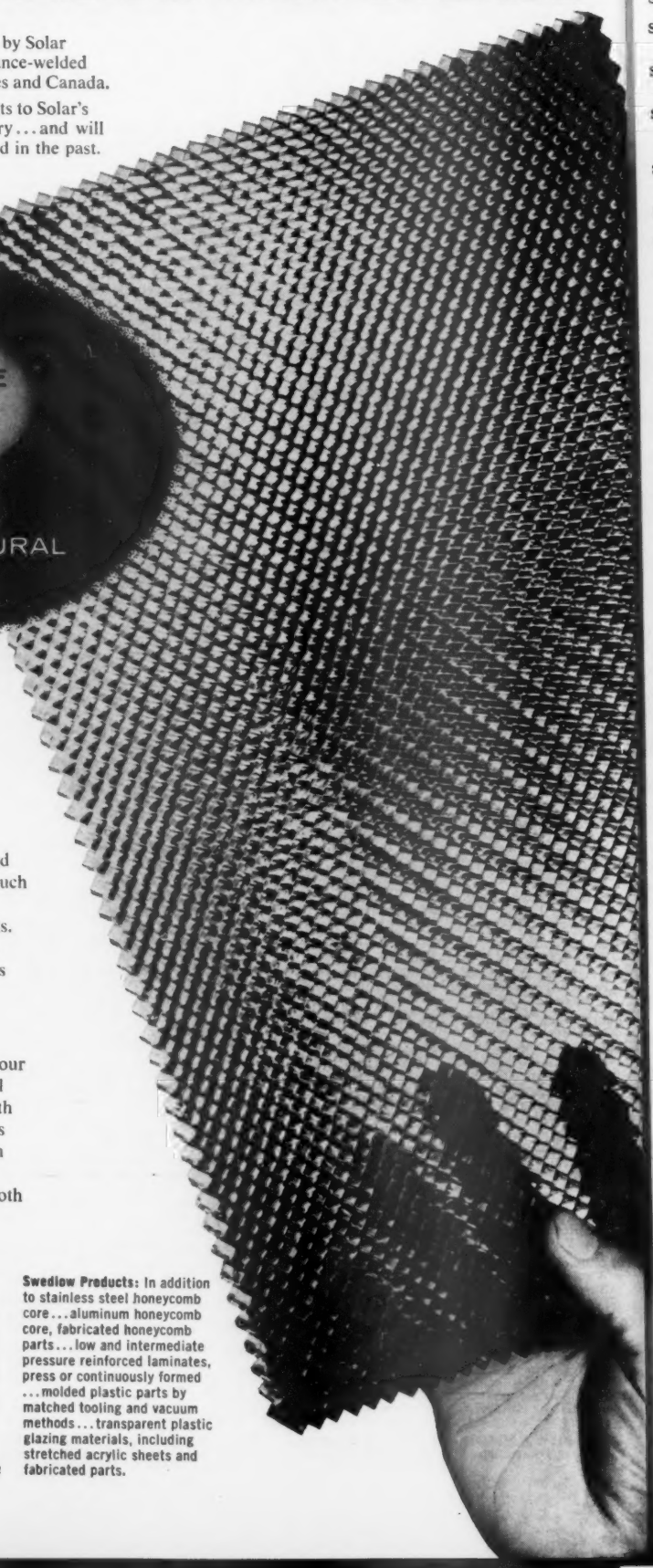

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Safety News Letter, Air Transp. Sect. Safety News Letter, Air Transport Section. National Safety Council, Chicago 11, Illinois, M

Sailplane and Glider, 8 Lower Belgrave St., London SW 1, England, BM, 12s. 9d.

Saro Prog. Saro Progress. Saunders-Roe Ltd., East Cowes, Isle of Wight, England, Q

SBAC Press Summary. Society of British Aircraft Constructors, 29 King St., St. James's, London SW 1, England, W

Schw. Aero-Rev. Schweizer Aero-Revue, Aero-Club der Schweiz, Hirschengraben 22, Zurich, Switzerland, M, 18 Sw. fr.

Sci. Mo. The Scientific Monthly. American Assn. for the Advancement of Science, 1515 Mass. Ave., NW, Washington 5, D.C., M, $7.50

Science. American Assn. for the Advancement of Science, 1515 Mass. Ave., NW, Washington 5, D.C., W, $7.50

Science Record. Science Press, 38 Suchou Hutung, Peking, China, Irreg.

Scientia Sinica. Academia Sinica, 38 Suchou Hutung, Peking, China, Irreg.

Ser. Selec. Papers Phys. Series of Selected Papers in Physics. Physical Society of Japan, Dept. of Physics, Faculty of Science, University of Tokyo, Bunkyo, Tokyo, Japan, Irreg.

Shell Av. News. Shell Aviation News. Aviation Dept., Shell Oil Co., 50 W. 50 St., New York 20, N.Y., M

Shorts Quart. Rev. Shorts Quarterly Review. Short Brothers & Harland Ltd., Queen's Island, Belfast, Ireland, Q

Sky & Tel. Sky & Telescope, Harvard College Observatory, 60 Garden St., Cambridge 38, Mass., M, $5

Skyline. North American Aviation, Inc., International Airport, Los Angeles 45, Calif., Q

Skyways, 122 E. 42 St., New York, N.Y., M, $4

SLAE J. Society of Licensed Aircraft Engineers, Journal (incorporating The Technical Instructor), 1 High St., Maidenhead, Berkshire, England, M, 30s.

So. Afr. Interpl. Soc. J. South African Interplanetary Society, Journal, P.O. Box 2330, Johannesburg, Union of South Africa, Q, 10s.

Soaring. Soaring Society of America and the Soaring Assn. of Canada, P.O. Box 71, Elmira, N.Y.; Ferguson Rd., Dallas 28, Tex., BM, $4

Soc. Ingr. Civils de France Bul. Société des Ingénieurs Civils de France, Bulletin, 19 rue Blanche, Paris 9, France, SM, 3,000 fr.

Soc. Ingr. Civils de France Mém. Société des Ingénieurs Civils de France, Mémoires, 19 rue Blanche, Paris 9, France, BM, 2,800 fr.

Soc. Inst. Tech. Trans. Society of Instrument Technology, Transactions, 4, Grosvenor Gardens, London SW 1, England, Q, £2 10s.

Solar Blast. Solar Aircraft Co., San Diego 12, Calif., Q

Sov. Phys.—Acous. Soviet Physics—Acoustics, American Institute of Physics, 57 E. 55 St. New York 22, N.Y., Q, $20

Sov. Phys.—Dokl. Soviet Physics—Doklady (Physics Section), American Institute of Physics, 57 E. 55 St., New York 22, N.Y., BM, $25

Sov. Phys.—JETP. Soviet Physics—JETP (Journal of Experimental and Theoretical Physics), American Institute of Physics, 57 E. 55 St., New York 22, N.Y., M, $64

Sov. Phys.—Tech. Phys. Soviet Physics—Technical Physics, American Institute of Physics, 57 E. 55 St., New York 22, N.Y., M, $90

Spaceflight. British Interplanetary Society, 12 Bessborough Gardens, London SW 1, England, Q

SPE J. Society of Plastic Engineers, Journal, 35 East Putnam Ave., Greenwich, Conn., M, $4

Sperry Eng. Rev. Sperry Engineering Review, Sperry Gyroscope Co., Great Neck, N.Y., BM

Sperry Rev. The Sperry Review. The Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middlesex, England, SA

Sperryscope. Sperry Rand Corp., 30 Rockefeller Plaza, New York 20, N.Y., Q

SRI J. Stanford Research Institute, Journal, Menlo Park, Calif., Q, $4

Steel Processing & Conversion, 624 Grant Bldg., Pittsburgh 30, Pa., M, $2.50

Strojniski Vestnik. Aškerčeva 28, Ljubljana, Yugoslavia, Q, 520 din.

Stud. Cerc. Mec. Aplic. Studii si Cercetari de Mecanica Aplicata. Academia Republicii Populare Romine, Bucarest, Rumania, Q

Stud. Cerc. Stiint. Studii si Cercetari Stiintifice. Academia Republicii Populare Romine, Bucarest, Rumania, Q

Sylvania Technologist. Sylvania Electric Products, Inc., Bayside, N.Y., Q, $1.50

Taylor Tech. Taylor Technology. Taylor Instrument Companies, Rochester 1, N.Y., Q

Tec. Ital. Technica Italiana. Consiglio Nazionale delle Ricerche, via Beccaria 6, Trieste, Italy, M, L. 6,000

Tech. et Sci. Aéronautiques. Technique et Science Aéronautiques. Assn. Française des Ingénieurs et Techniciens de l'Aéronautique (AFITA), 6 rue Cimarosa, Paris 16, France, BM

Tech. Lotnicza. Technika Lotnicza, Nowowiejska 24, Warsaw 10, Poland, BM, 54 zl.

Tech. News Bull. Technical News Bulletin. U.S. National Bureau of Standards. Supt. of Documents, Washington 25, D.C., M, $1

Tech. Rev. The Technology Review. MIT, Cambridge 39, Mass., M, $4

Tek. Tidsk. Teknisk Tidskrift. Svenska Teknologföreningen, Box 841, Stockholm 1, Sweden, W, 50 kr.

Teploenergetika. Ministerstvo Elektrostantsii SSSR—Akademiia Nauk SSSR, Moscow, USSR, M

Tex. Eng. Exp. Sta. News. Texas Engineering Experiment Station News, College Station, Tex., Q

Thermik, Obere Maschstrasse 8, Göttingen, Germany, M, DM 10

Thompson Prod. Eng. Bul. Thompson Products Engineering Bulletin. Thompson Products, Inc., 23555 Euclid Ave., Cleveland 17, Ohio, Irreg.

Thrust. Fairchild Engine Div., Fairchild Engine and Airplane Corp., Deer Park, N.Y., Q

Tôhoku U. Rep. Inst. High Speed Mech. Tôhoku University, Institute of High Speed Mechanics, Reports, Sendai, Japan

Tool Engr. Tool Engineer. American Society of Tool Engineers, 10700 Puritan Ave., Detroit 38, Mich., M, $6

Trend in Eng. The Trend in Engineering. Engineering Experiment Station, University of Washington, Seattle 5, Wash., Q

U.S. Air Serv. U.S. Air Services, Transportation Bldg., Washington 6, D.C., M, $3

U.S. Nav. Inst. Proc. United States Naval Institute, Proceedings, Annapolis, Md., M, $3

VDI-Zeitschrift. Verein deutscher Ingenieure, Bongardstrasse 3, Düsseldorf, Germany, 36 issues per pear, DM 80

Vickers Mag. Vickers, Ltd., Vickers House, London SW 1, England, SA

Vitesse-Speed, 28, rue Vaneau, Paris 7, France, M

De Vliegende Hollander. Royal Netherlands Air Force, Gevers Deynootplein 5, Scheveningen, Netherlands, M, 5.50 fl.

W. U. Tech. Rev. Western Union Technical Review. Western Union Telegraph Co., 60 Hudson St., New York 13, N.Y., Q, $1.50

Wasserwirtschaft, Pfizerstrasse 5-7, Stuttgart, Germany, M, DM 30

Welding J. Welding Journal. American Welding Society, 33 W. 39 St., New York 18, N.Y., M, $7

Weltraumfahrt, Stuttgarterstr. 20, Frankfurt a.M., Germany, Q, DM 9.84

Western Av. Western Aviation, 4328 Sunset Blvd., Los Angeles 29, Calif., M, $3

Westinghouse Engr. Westinghouse Engineer. Westinghouse Electric Corp., P.O. Box 2278, 3 Gateway Center, Pittsburgh 30, Pa., BM, $2.50

Whites Av. Whites Aviation, Dilworth Bldg., Queen St., Auckland, New Zealand, M, $3

Wings. Royal New Zealand Aero Club, Inc., 1 Marion St., Wellington, N.Z., M, 15s.

Wireless Engr. Wireless Engineer, Dorset House, Stamford St., London SE 1, England, M, $7.50

Wireless World, Dorset House, Stamford St., London SE 1, England, M, $5

WMO Bul. WMO Bulletin. World Meteorological Organization, Campagne Rigot, ave. de la Paix, Geneva, Switzerland, Q, 4 Sw. fr.

ZAMM. Zeitschrift für angewandte Mathematik und Mechanik, Mohrenstr. 39, Berlin W8, Germany, M, DM 60

ZAMP. Zeitschrift für angewandte Mathematik und Physik, Basel 10, Switzerland, BM, 48 Sw. fr.

ZFW. Zeitschrift für Flugwissenschaften. Wissenschaftliche Gesellschaft für Luftfahrt e.V. (WGL), Burgplatz 1, Braunschweig, Germany, M, DM 48

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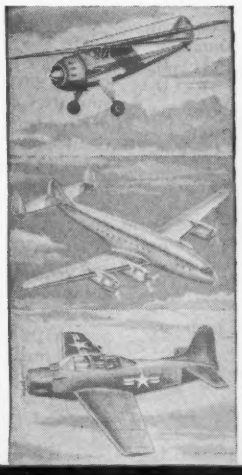

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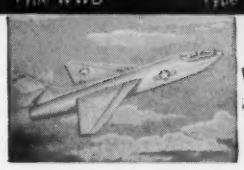

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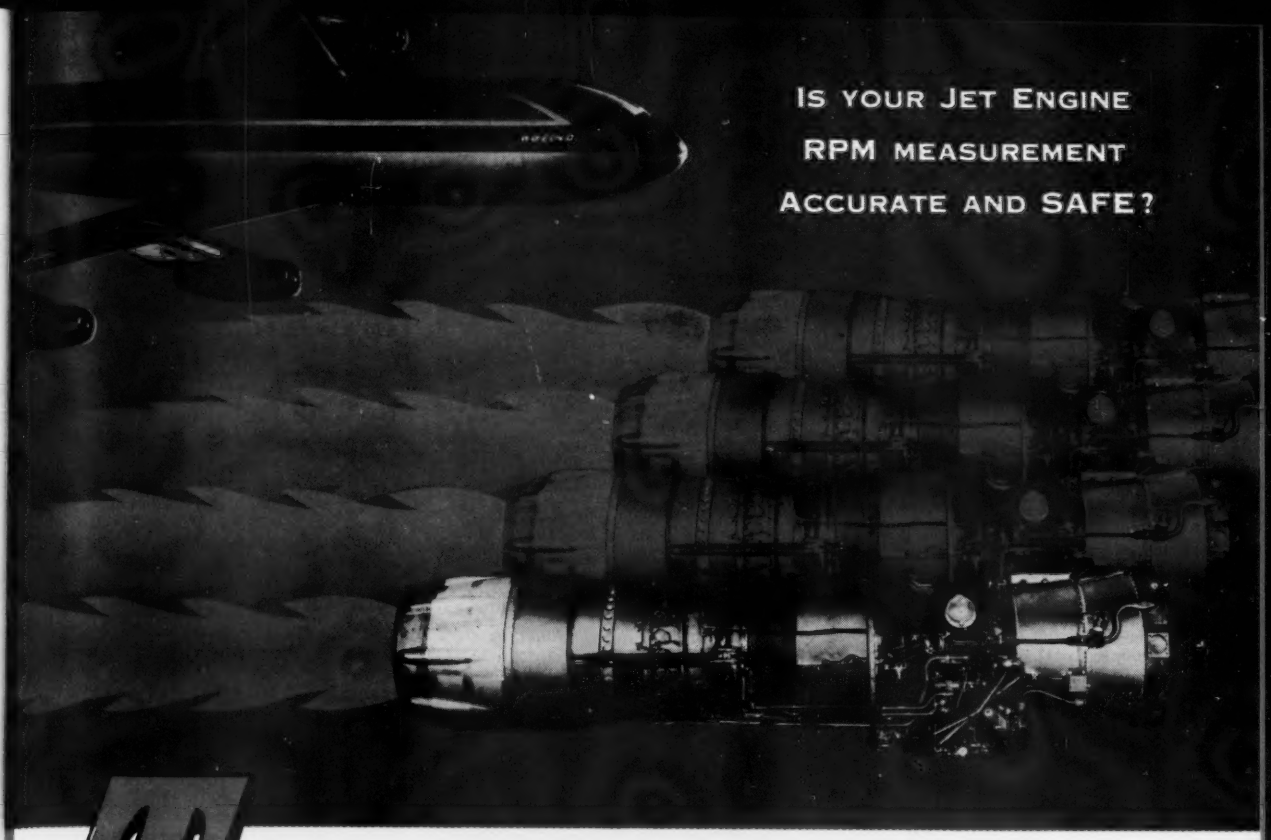

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instead of the present 5 psi; the reduction of general noise and vibration levels; and installation of a tail skid under the aft fuselage.

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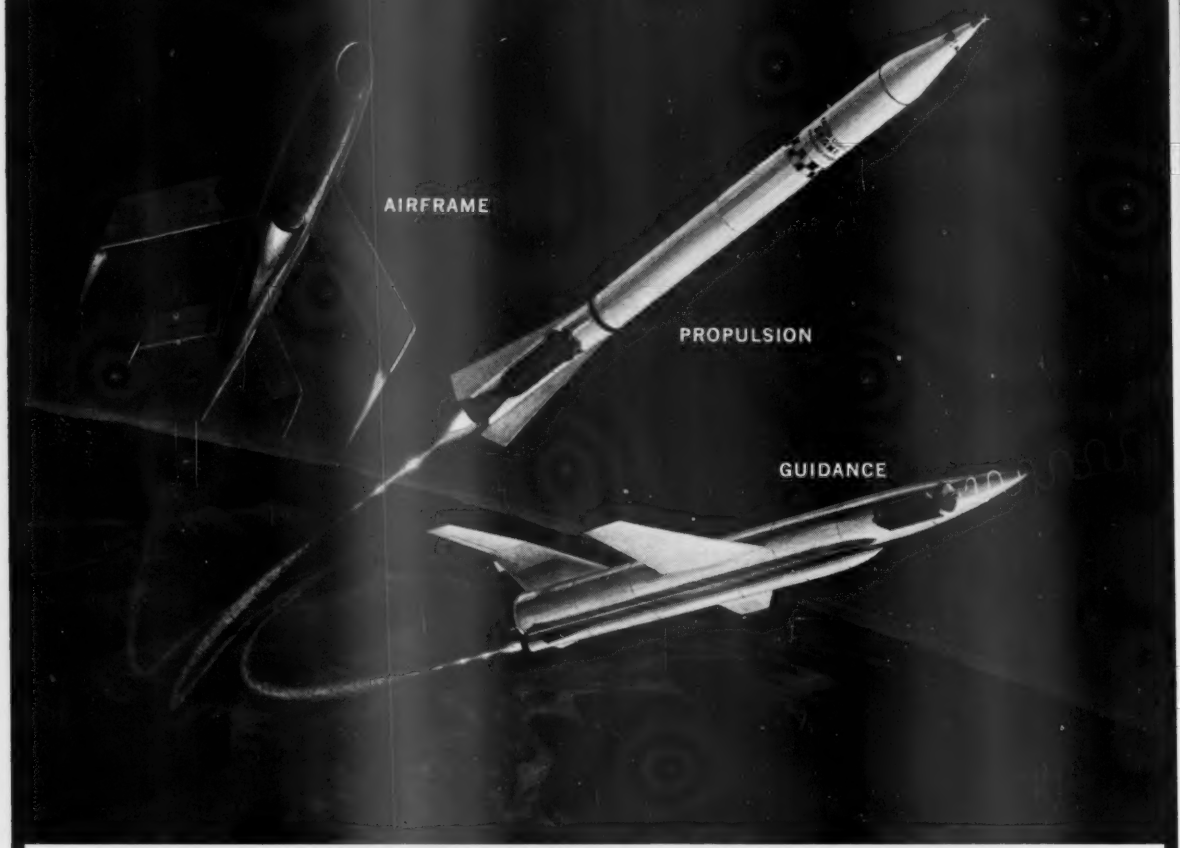

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PUBLISHED MONTHLY BY THE AERONAUTICAL ENGINEERING REVIEW

Official Publication of the Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

Volume 3. Number 1 January, 1958

AERODYNAMICS

Aerothermodynamics

ADVANCEMENT OF A COMPRESSIBLE HEAT CONDUCTING FLUID OVER AN INFINITE FLAT PLATE. A. S. Gupta. ZAMM, Sept.-Oct., 1957, pp. 349-353. Integration in semi-convergent expressions of the equations of motion in the unsteady case when a compressible viscous fluid with vanishing pressure gradients flows past an infinite flat plate and when the physical constants depend on temperature. Simple expressions are obtained for temperature and velocity distribution in the boundary layer, the drag coefficients, and their dependence on physical constants.

HEAT TRANSFER AND RECOVERY TEMPERATURES ON A SPHERE WITH LAMINAR, TRANSITIONAL, AND TURBULENT BOUNDARY LAYERS AT MACH NUMBERS OF 2.00 AND 4.15. Appendix - HEAT-METER CORRECTIONS. I. E. Beckwith and J. J. Gallagher. US, NACA TN 4125, Dec., 1957. 59 pp. 17 refs. Investigation of the pressure, equilibrium temperatures, and aerodynamic heat transfer on a sphere and on the nose of a hemisphere cylinder. The heat-transfer coefficients and recovery temperatures from the stagnation point to transition show good agreement with the theories for the laminar boundary layer. Transition occurs at an angular distance from the stagnation point of 10° to 30° at Mach Number 2.00 and from 30° to 90° at Mach Number 4.15. The heat transfer coefficients and recovery temperatures in the turbulent boundary layer are in reasonable agreement with simple theories for turbulent flow.

HEAT TRANSFER AND BOUNDARY-LAYER TRANSITION ON TWO BLUNT BODIES AT MACH NUMBER 3.12. Appendix A, B - STAGNATION-POINT HEAT-TRANSFER COEFFICIENT FOR VARIABLE WALL TEMPERATURE. N. S. Diaconis, R. J. Wisniewski, and J. R. Jack. US, NACA TN 4099, Oct., 1957. 31 pp. 14 refs. Investigation on a 120°-included-angle cone-cylinder at free stream unit Reynolds Numbers as high as 12.92×10^5 per inch. Values of the Stanton Number computed for both configurations (smooth surface, roughness < 16 microin.) indicate good agreement with theory. The ratio of experimental to theoretical stagnation-point heat transfer rate appeared to be a function of roughness Reynolds Number. Transition results on both bodies showed an increase in transition Reynolds Number with increase in wall temperature. For a given wall temperature both surface roughness size and unit Reynolds Number have a large effect on the transition.

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STATIONÄRE WANDTEMPERATUREN FLIEGENDER KÖRPER UNTER DEM EINFLUSS AERODYNAMISCHER ERWÄRMUNG IM FLUGMACH-ZAHLBEREICH 1-10 UND IM FLUGHÖHENBEREICH BIS 30 KM. H. G. L. Krause and M. E. Kübler. Forschungsinst. Phys. Strahlantriebe Mitteil. 7, Oct., 1957. 138 pp. 61 refs. In German. Study of stationary wall-temperatures of missiles under the influence of aerodynamic heating in a Mach Number range of 1-10 and at flight altitudes

up to 30 km. Charts and curves of the equilibrium wall-temperatures are included. The thermal velocity-limit is examined, using the methods of thermo-chemical boundary-layer flow, under the assumption, that the aircraft surfaces show a diffused reflexion of the striking air molecules. It is concluded, that the actual thermal velocity-limit in horizontal flight cannot be extended above the Mach Number range investigated, unless internal wall-cooling or boundary-layer suction are applied.

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AN EXPERIMENTAL STUDY OF THE BOUNDARY LAYER BEHIND A MOVING PLANE SHOCK WAVE. W. A. Martin. UTIA Rep. 47, May, 1957. 65 pp. 32 refs. Description of measurements using interferometry to determine the density distribution through the turbulent boundary layer developed on the floor of the UTIA 2-in. x 7-in. shock tube behind shock waves of pressure ratios 2.75 and 8.00. Velocity profiles are calculated from the density measurements assuming constant pressure throughout the flow and using Crocco relationship between temperature and velocity. With velocity and density determined it is possible to compute the displacement and momentum thickness for the boundary layer. Local skin friction is calculated using the slope of the momentum thickness curve.

ON ASYMPTOTIC EXPANSION IN THE THEORY OF BOUNDARY LAYERS. K. Stewartson. J. Math. & Phys., Oct., 1957, pp. 173-191. 11 refs. Analysis considering the effect of the neglected boundary conditions in finding the stage in which this condition first affects the asymptotic expansion of the stream function. Four problems are considered. The first is the flow in the wake of a flat plate at a large distance x downstream from the plate. The second is hypersonic flow over a flat plate at a large distance x from the leading edge. The third is the asymptotic boundary layer on a semi-infinite circular cylinder when the main stream direction is parallel to the generators. The last problem considers the suction boundary layer on a flat plate.

EFFECTS OF EXTREME SURFACE COOLING ON BOUNDARY-LAYER TRANSITION. J.R. Jack, R. J. Wisniewski, and N. S. Diaconis. (High-Speed Aerodynamics & Struc. Symp., Gainesville, Fla., Jan. 22-24, 1957.) US, NACA TN 4094, Oct., 1957. 19 pp. 10 refs. Investigation to determine the combined effects of surface cooling, pressure gradients, nose blunting, and surface finish on boundary layer transition. Data are obtained for various body shapes at a Mach Number of 3.12 and Reynolds Numbers per foot as high as 15×10^6. For surface roughnesses ranging from 4 to 1,250 micro-inches the location of the transition is unaffected with moderate cooling. With extreme cooling, an adverse effect is observed for each of the parameters investigated. In general, the transition Reynolds Number decreased with decreasing surface temperatures. In particular, the beneficial effects of a favorable pressure gradient obtained with moderate cooling disappear with extreme cooling, and a transition Reynolds Number lower than that observed on a cone is obtained. Further, an increase in the nose bluntness decreased the transition Reynolds Number under conditions of extreme cooling.

DAS ANWACHSEN DER GRENZSCHICHT IN UND HINTER EINER EXPANSIONSWELLE. E. Becker. Ing.-Arch., No. 3, 1957, pp. 155-163. 11 refs. In German. Study of the boundary layer growth in laminar and turbulent flow inside and behind an expansion wave, and presentation of simple approximate equations based on the momentum theorem. The gas moves parallel to the plane wall and in opposite direction to the wave expansion. The gas velocity, U, assumes a constant value, U_1, behind the wave. The progressive wave becomes plane, and the distance between the wave tip and wave end increases. The boundary layer forms after the passage of the leading wave.

MOMENTUM TRANSFER FOR FLOW OVER A FLAT PLATE WITH BLOWING. H. S. Mickley and R. S. Davis. US, NACA TN 4017, Nov., 1957. 64 pp. Investigation of the effect on the boundary layer of blowing air through a porous flat plate into a main airstream flowing parallel to the plate. Measurements are made of velocity profiles and wall friction coefficients. The dimensionless ratio v_o/u_1 of blowing velocity to main-stream is maintained constant, independent of length, in a given experiment. The experimental results are compared with previous work and significant differences are observed. In particular, at the same values of v_o/u_1 and Reynolds Number, the present experiments result in friction coefficients 15 to 30% smaller than those reported earlier.

EFFECT OF FREE CONVECTION ON THE COEFFICIENT OF RESISTANCE OF A PLATE WITH A LAMINAR FLOW REGIME IN THE BOUNDARY LAYER. A. A. Tanaev. Sov. Phys. - Tech. Phys., No. 11, 1957, pp. 2,477-2,483. Translation. Analysis of the effects of gravity on laminar boundary layer for the case of streamline flow in a compressible gas around a flat plate with small values for Froude's criterion.

Fluid Mechanichs & Aerodynamic Theory

ON A STATISTICAL THEORY FOR ONE-DIMENSIONAL REAL GAS FLOWS. Paul Lieber and Koon-Sang Wan. Rensselaer Polytech. Inst. Dept. Geol. Rep. (AFOSR TN 57-478) [AD 136470], Sept. 1957. 23 pp. Development of a theory for obtaining in compressible-viscous flows a set of governing conditions that are mathematically tractable and yet represent the essential physical phenomena. The governing equations are formulated in terms of physical parameters representing the mass density, the mass flow velocity, and the root mean square of the velocity fluctuations relative to the mean velocity. In addition, a characteristic length is introduced to represent the mean free path. The theory yields a relation across a normal shock wave in agreement with the Rankine-Hugoniot theory, and may be extended to two dimensions with the object of calculating flows where compressibility and viscosity effects are both prominent.

K TEORII GAZOVYKH STRUI. S. V. Fal'kovich. Prikl. Mat. i Mekh., 1957, pp. 459-464. In Russian. Investigation of gas flows taking into account Chaplygin's method for the solution of the problem of plane, laminar, adiabatic flow of a gas in a region with rectilinear boundaries and free surfaces (streams) where the velocity has a constant value not higher than the speed of sound. This method is applied to the case with only one given velocity. The treatment shows how this limitation could be avoided and leads to a set of new exact solutions for the subsonic flow of gas.

THE FUNDAMENTAL SOLUTION FOR SMALL STEADY THREE-DIMENSIONAL DISTURBANCES TO A TWO-DIMENSIONAL PARALLEL SHEAR FLOW. M. J. Lighthill. J. Fluid Mech., Nov., 1957, pp. 113-144. 15 refs. Development of equations to represent secondary flow due to a weak source in a parallel shear flow, neglecting the square of the disturbance due to the presence of the source. The theory is applied for small and large distances from the origin, and to theorems for shear layers with small total variation in velocity. The relationship between the present solution and exact-profile secondary flow is examined, along with theories on the displacement of the stagnation streamline.

A STUDY LEADING TO THE BOUNDARY CONDITIONS AT A FREE SURFACE JOINING AN IRROTATIONAL-ROTATIONAL FLOW REGIME. Paul Lieber and Koon-Sang Wan. Rensselaer Polytech. Inst. Dept. Geol. Rep. (AFOSR TN 57-480) [AD 136472], Sept., 1957. 11 pp. Theoretical demonstration that, as a consequence of the boundary conditions assigned at the interface, the curvature of the interface is necessary for terminating the rotational regime. Therefore, the mechanisms which terminate the rotational regime are related to the mechanism which produces the curvature called for at the interface. In investigating these mechanisms, a number of elementary flow configurations calculated according to the principle of stationary dissipation are considered. The problem of a two-dimensional viscous incompressible flow produced by a circular cylinder is investigated in three stages. The first consists of obtaining a solution to the classical problem treated by Stokes; the second encloses the cylinder by two fixed boundaries and calculates the resulting flow; the third frees the portions of the boundaries arbitrarily fixed in the second stage.

THE ASYMPTOTIC EXPANSIONS AT LARGE REYNOLDS NUMBERS FOR STEADY MOTION BETWEEN NON-COAXIAL ROTATING CYLINDERS. W. W. Wood. J. Fluid Mech., Nov., 1957, pp. 159-175. Investigation of the motion of a viscous fluid between two rotating, circular-cylinders whose axes are set slightly apart. The equations of viscous motion are linearized by expanding the stream function. The analysis is valid for all values of fluid viscosity ν, and in particular for small values of ν. Examination of the asymptotic behavior of the solution for small ν, considering, in particular, the first-order stream function ψ_1 and the corresponding component of vorticity ζ_1. It is noted that the asymptotic expansions of ψ_1 for the region of the boundary layers and for the region outside the boundary layers may be combined into a single expansion which holds in both regions. The leading terms of the expansion are calculated by boundary layer methods.

SKIN FRICTION ON A STRIP OF FINITE WIDTH MOVING PARALLEL TO ITS LENGTH. Harold Levine. J. Fluid Mech., Nov., 1957, pp. 145-158. 10 refs. Study of a flat strip of infinitesimal thickness and infinite length located in a viscous incompressible fluid. Both the strip and the fluid are at rest initially. The strip is abruptly set into steady motion parallel to its length. An unsteady unidirectional flow of the fluid results, and there is a variable skin friction on the strip which must be overcome to maintain its velocity. A calculation is made, based on a new integral equation which makes explicit the effect of an isolated edge and by iteration provides the interaction effects between edges at a finite separation.

BETRACHTUNGEN ZUM AUFSPULVORGANG DER HINTER EINEM TRAGFLÜGEL BEIM GERADEAUSFLUG ENTSTEHENDEN WIRBELSCHICHT. W. Kaufmann. ZFW, Nov., 1957, pp. 327-331. 12 refs. In German. Evaluation of the theory of rolling up vortex sheets, based on the assumption of an inviscid fluid, and the two separate vortices

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formed are considered as potential vortices. On the basis of this idealization, the distance between the two separate vortices can be calculated by the conventional method. However, all the available measurements have shown the theoretically obtained distance to be smaller that the experimental distance. An attempt is made to define the discrepancy between theory and experiment by neglecting the idealizations.

PROPAGATION OF AN APERIODIC WAVE IN A COMPRESSIBLE VISCOUS MEDIUM. Meir Hanin. J. Math. & Phys., Oct., 1957, pp. 234-249. 11 refs. Presentation of nonperiodic solutions for the third order parabolic differential equation with constant coefficients that govern the propagation of plane waves in a visco-elastic solid. This involves waves generated in an originally quiescent medium by known disturbances at a given plane. Solutions are given for a Dirac-pulse disturbance since this solution may be regarded as a fundamental case of the general solution, and because the damping effects of viscosity should reveal themselves clearly.

THE EFFECT OF A VARIABLE EVAPORATION RATE ON THE BALLISTICS OF DROPLETS. C. C. Miesse. Franklin Inst. J., Nov., 1957, pp. 391-401. WADC-sponsored analysis considering the ballistics equations and evaporation (Frössling's) equations simultaneously in order to allow for the effect on its velocity and diameter of the variation in evaporation rate of a liquid droplet with its Reynolds Number. The resultant nonlinear equation yields analytical solutions for discrete values of the viscosity/still-air-evaporation rate parameter, which permits ready determination of the variation in drop size and relative velocity with time or distance. The results indicate that the constant evaporation rate analysis is valid for large values of the still-air-parameter, but should be modified for smaller values.

STUDY OF PRESSURE DISTRIBUTIONS ON SIMPLE SHARP-NOSED MODELS AT MACH NUMBERS FROM 16 TO 18 IN HELIUM FLOW. W. D. Erickson. US, NACA TN 4113, Oct., 1957. 42 pp. 17 refs. Investigation indicating that the pressure distributions obtained for the flat plate differ from the prediction of Lees for the strong interaction region by an amount which may be accounted for by the finite thickness of the leading edge. The wedge results are believed to be influenced by a bleedoff effect which results in a lower surface pressure than predicted by the viscous-interaction theory. The results for the 5° to 10° cones show better agreement with the Taylor-Maccoll prediction as the cone angle becomes larger. Temperature recovery factors are also presented and agree with the Prandtl Number relationship.

ELLIPTIC CONES ALONE AND WITH WINGS AT SUPERSONIC SPEEDS. L. H. Jorgensen. US, NACA TN 4045, Oct., 1957. 55 pp. 18 refs. Wind-tunnel investigation indicating that distinct aerodynamic advantages can result from the use of elliptic rather than circular cones for flight at supersonic speeds. With their major cross-sectional axes horizontal, they develop greater lift and have higher lift-drag ratios than comparable circular cones. In combination with triangular wings of low aspect ratio they also develop higher lift drag ratios than circular cones with the same wings. Visual-flow studies indicate that vortex flow is inhibited more for an elliptic cone with major axis in the plane of the wing, resulting in a reduction of vortex drag due to lift. Shifts in center of pressure with changes in angle of attack and Mach Number are small and about the same as for circular cones.

AN EXPERIMENTAL INVESTIGATION OF THE OSCILLATING PRESSURES ON A CIRCULAR CYLINDER IN A FLUID STREAM. D. M. McGregor. UTIA TN 14, June, 1957. 35 pp. Test results obtained on a cylinder mounted in a wind tunnel at right angles to the flow and containing within it the microphone used as the pressure transducer. By making assumptions about the correlation of the pressure around the circumference of the cylinder, estimations are made by integration of the surface pressure coefficients of the oscillating lift and drag coefficients of the cylinder. It is found that the pressure level of the fundamental frequency is very low at the front of the cylinder, but rises sharply to a maximum at the sides. After remaining constant over an appreciable arc (approximately 60°), it decreases to the background level at the rear. The level of the second harmonic is masked by the background except in the rear 1/3 of the cylinder where it increases steadily to a maximum in the downstream direction.

BEEINFLUSSUNG DER LAGE DES VERDICHTUNGSSTOSSES BEI PROFILEN IN HOHER GESCHWINDIGKEIT. H. Ch. Sharaf. Max-Planck-Inst. für Strömungsforschung, Mitteil., No. 16, 1957. 63 pp. 46 refs. DM 7. In German. Study of the locally supersonic areas for a profile in high subsonic flow. A half model of the profile is attached to a plane wall and the boundary on the wall in front of the profile is eliminated by suction through the wall. The effects of Mach Number, profile shape, and boundary layer suction on the supersonic areas and location of compression shock are determined by pressure measurements and schlieren photographs. The occurrence of multiple, serial, shock locations is also investigated.

RECENT DEVELOPMENTS IN HYPERSONIC FLOW. Lester Lees. (ARS Semi-Annual Meeting, San Francisco, June 10-13, 1957.) Jet Propulsion, Nov., 1957, pp. 1,162-1,178. 66 refs. Army-supported review of theoretical and experimental work done within the last two years on inviscid-flow aerodynamics and viscous interactions on blunt-nosed bodies. Hayes has shown that the lateral flow over a nearly flat-faced body is governed by a choking mechanism at the shoulder, and recent experiments have confirmed this statement. At hypersonic velocity, the transverse flow field produced by a blunt-nosed slender body in a fixed plane nor-

mal to the flight direction is analogous to the flow generated by an expanding blast wave. A brief discussion of the "power" body and the hemisphere cylinder shows two important problems: (1) emergence of the boundary layer from the "blanket" of low Mach Number gas generated by the strong portion of the bow shock, (2) the effects of a transverse curvature on the viscous layer in the presence of axial pressure gradients that may be partially self-induced.

THE CHARACTERISTICS OF TWO-DIMENSIONAL SAILS IN HYPERSONIC FLOW. Walter Daskin and Lewis Feldman. J. Aero. Sci., Jan., 1958, pp. 53-55. Investigation of aerodynamic and geometric characteristics of sails using surfaces having large values of lift and/or drag per unit weight. Simple closed expressions are derived for the sail shape and the corresponding lift, drag, and moment coefficients. Includes charts of these quantities for the entire design range. Results can also be applied to two-dimensional parachutes.

AN APPROXIMATE SOLUTION OF THE HYPERSONIC LAMINAR BOUNDARY-LAYER EQUATIONS AND ITS APPLICATION. Tosimitu Nagakura and Humio Naruse. Phys. Soc. Japan J., Nov., 1957, pp. 1, 298-1, 304. 15 refs. Derivation of approximate formulas for the displacement thickness and skin friction using von Kármán's integral method, assuming the heat-insulated wall, a Prandtl Number of unity, and Chapman and Rubesin's formula for the variation in viscosity with temperature. The results are compared with exact solutions and show good agreement. These formulas together with the tangent-wedge approximation are applied to the viscous flow over slender bodies with a sharp leading edge. As an example the pressure distribution over a flat plate is calculated numerically over the entire region of the surface.

NUMERICAL CONSTRUCTION OF DETACHED SHOCK WAVES. P. R. Garabedian. J. Math. & Phys., Oct., 1957, pp. 192-205; Discussion, C. C. Lin, pp. 206-209. 11 refs. ONR-sponsored analysis for the problem of a detached shock wave in front of a blunt obstacle which moves at supersonic speed. A method is developed, based on complex variables, for the numerical calculation of the flow in the subsonic region between the shock wave and the obstacle. The method is applied to study the dependence on the Mach Number of the ratio of the distance between the shock wave and obstacle, to the radius of curvature of the latter. A procedure is developed for a numerical treatment by finite differences of the Cauche problem, thus overcoming the difficulties stemming from the ellipticity of the differential equations governing motion in a subsonic region.

A STUDY ON THE ATTENUATION OF SHOCK WAVES DUE TO OBSTACLES IN THE PASSAGE. Ryuma Kawamura and Haruo Kawada. Phys. Soc. Japan J., Nov., 1957, pp. 1, 290-1, 298. Theoretical and experimental investigation of the retardation of shock waves due to obstacles in the passage. A one-dimensional analysis is applied to the flow field resulting from the interaction of shocks and obstacles, and a theoretical relation between attenuation of shocks and the resistance of the passage is derived. The drag coefficients of a series of simple bluff obstacles used in the experiment are estimated, and comparisons are made with available steady-flow data.

SOME CHARACTERISTICS OF THE UPPER ATMOSPHERE PERTAINING TO HYPERVELOCITY FLIGHT. C. F. Hansen. (ARS Semi-Annual Meeting, San Francisco, June 10-13, 1957.) Jet Propulsion, Nov., 1957, pp. 1,151-1,156. 16 refs. Discussion of the chemical processes which occur in the air and of their effects on the density and temperature structure of the atmosphere. The reactions responsible for most of the solar energy absorption are outlined along with the major rate controlling reactions which determine the atmosphere's state of chemical equilibrium. It is demonstrated that owing to low density most of the aerodynamic force and heat transfer effects become secondary above 60 miles altitude, for vehicles traveling at speeds up to escape velocity. Meteor and cosmic particle problems which arise at high altitude are considered in relation to flight.

ON THE FINE STRUCTURE OF TURBULENT FLOWS. R. Betchov. J. Fluid Mech., Nov., 1957, pp. 205-216. 15 refs. Investigation of the turbulence produced by a multiplicity of small air jets and a comparison is made with other turbulent flows. The energy spectrum is measured, as well as the skewness and kurtosis of $\partial u/\partial x$. The effect of the finite length of the hot wire is considered and the corrected results indicate that the spectrum follows the law of Kolmogoroff in an intermediate range and appears to fall off with the (-6)-power of the frequency in the viscous range. The ultimate limit to spectral analysis is imposed by the molecular agitation of the gas. This limit is evaluated and compared with the spectrum of turbulence. It appears that the spectrum of $\partial^3 u/\partial x^3$ merges with the spectrum of molecular agitation without a distinctive separation.

ON THE EFFECT OF FREE-STREAM TURBULENCE ON THE STRUCTURE OF TURBULENT WAKE. Hiroyuki Komoda. Japan Soc. Aero. Eng. J., Oct., 1957, pp. 6-11. 10 refs. Results of hot-wire experiments in the wake behind a circular cylinder (1-mm diam.) in an air stream whose velocity is 10 m/sec. The measurements are made for two cases: (a) when the free stream is undisturbed and (b) when a disturbance is produced by inserting a grid in such a way that the scale of the resulting turbulence is comparable to the width of the wake. It is found that the effect of free-stream turbulence increases the turbulent intensity of the wake.

PROCEEDINGS OF THE MEETING ON TURBULENCE. (Math. Res. Inst. Meeting, Oberwolfach,

May 11-14, 1957.) USAF EOARDC Rep. (AFOSR TN 57-529) [AD 136514], June, 1957. 24 pp. Summary of papers presented on turbulence theory with discussions on its dynamics, the effects of viscosity, transition probabilities, and applications of statistical and symbolic tensor calculus to the theory.

CALCULATION OF THE CROSS-STREAM WAVE LENGTH OF THE THREE-DIMENSIONAL TRANSITION PATTERN AND CORRELATION WITH THE GORTLER INSTABILITY THEORY. J. R. Weske and Y. Y. Chen. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-111 (AFOSR TN 57-637) [AD 136625], Oct., 1957. 31 pp. Analysis of the mechanism producing a regular three-dimensional pattern at an early stage of transition in the boundary layer. Relations for secondary vorticity, in the case of rotational yet nonviscous flow, are used to derive quantitative relationships for the cross-stream wave length of this pattern for both uniform and retarded free flow. The results are linked to the Taylor-Gortler theory of instability along curved walls.

Internal Flow

ECOULEMENT D'UN FLUIDE ENTRE DEUX PLANS PARALLELES; CONTRIBUTION A L'ETUDE DES BUTEES D'AIR. Raymond Comolet. France, Min. de l'Air PST 334, 1957. 83 pp. 26 refs. SDIT, 2, Av. Porte-d'Issy, Paris 15, Frs. 1,100. In French. Systematic study of radial and longitudinal bi-dimensional viscous flows between two fixed surfaces, based on the polytropic-type transformation rule. The forces of inertia are taken into account. The obtained formulas refer to results obtained for more simple cases, and the experimental verifications indicate the field of application of the proposed formulas. In the radial and divergent case the flow is laminar and isothermic as long as the local Reynolds Number remains below 550.

VLIIANIE POGRANICHNOGO SLOIA NA KHARAKTER TECHENIIA GAZA V TRUBE ZA DVIZHUSHCHEISIA UDARNOI VOLNOI. Iu. A. Dem'ianov. Prikl. Mat. i Mekh., 1957, pp. 473-477. In Russian. Influence of the boundary layer on the character of gas flow in a duct behind a moving shock wave. The analysis of the obtained solution of a previously established problem and of the phenomena of acceleration of the contact surface in the shock tube. It is assumed that at $t = 0$ a shock wave is generated which moves into the gas at rest with a velocity U_0 followed by a uniform gas flow. It is also assumed that the variation in time of the velocity of the shock wave $U(t)$ and of the flow following it could be produced only by the formation of a boundary layer along the walls of the tube. It is assumed that the influence of the boundary layer leads to a small variation of the gas flow outside of it, which is considered as uni-dimensional.

UNSTEADY FLOWS IN AXIAL TURBOMACHINES. W. D. Rannie and F. E. Marble. France, ONERA, J. I. S. A., Paris, May 27-29, 1957, Comptes Rendus, Pt. 2, pp. 1-21. OSR-ONR-sponsored analysis of self-induced oscillations and forced disturbances in compressors. A special type of propagating stall appears as a self-induced disturbance; an asymmetric velocity profile introduced at the compressor inlet constitutes a forced disturbance. Both phenomena are treated from a unified theoretical point of view in which the asymmetric disturbances are linearized and the blade characteristics are assumed quasi-steady. For both disturbances the dominant blade characteristic is the dependence of total pressure loss, rather than the turning angle, upon the local blade inlet angle.

AXIALE RÜCKWIRKUNGEN VON ÜBERSCHALLSCHAUFELGITTERN. I. Ryhming. ZAMM, Sept.-Oct., 1957, pp. 370-385. In German. Study of the stationary case of supersonic flows or currents reacting on the incident flow in case of rapidly rotating bucket rings. The treatment includes both the linear approximation and the exact method. For cascades without guide vanes the Mach ratio of the afflux velocity to the velocity of sound is dependent on the rotational speed. Cascades with guide vanes show different types of flow.

ETUDE DES REGIMES CRITIQUES NON STATIONNAIRES DANS LE FONCTIONNEMENT A VITESSE REDUITE DES COMPRESSEURS D'AVIATION. R. Siestrunck, J. Fabri, and L. Jarlan. France, ONERA, J. I. S. A., Paris, May 27-29, 1957, Comptes Rendus, Pt. 2, pp. 83-114. 16 refs. In French. Experimental results obtained by the S. N. E. C. M. A. and O. N. E. R. A. for axial compressors with critical, nonstationary regimes at reduced velocities. Includes performance characteristics, rotating separation, blade excitation by rotating separation, and the basic theory of tangential and radial equilibrium.

ÜBER DIE BERÜCKSICHTIGUNG DES KOMPRESSIBILITÄTSEINFLUSSES BEI SCHAUFELGITTERSTRÖMUNGEN. Norbert Scholz. ZFW, Sept., 1957, pp. 265-269. In German. Consideration of the relations between the quantities of the inflow and the outflow for a two-dimensional compressible cascade flow. Exact equations are given, along with the linearized relations for small Mach Numbers. Using two universal diagrams, the calculation is reduced to the unambiguous and simple case of the incompressible cascade flow.

INVESTIGATION OF A WIDE ANGLE DIFFUSER WITH AIR AUGMENTATION FOR USE AS A JET MUFFLER. A. J. Campbell. UTIA TN 15, Aug., 1957. 20 pp. 14 refs. Description of a wide-angle diffuser and discussion of the possibility of reducing the noise source output by aerodynamic means, and to decrease the radiated sound by acoustic treatment. A large reduction in velocity and a small cooling air flow are attained by means of screens to prevent separation of flow. Experimental results indicate that grids of rods would also provide satisfactory resistance. However, the experiments indicate a pronounced noise augmenta-

tion in the case of rods. Includes development of a theory for qualitative prediction of the induced air flow when a short mixing length is used.

AN EXPERIMENTAL INVESTIGATION OF THE PRESSURE RECOVERY OF A PERFORATED-WALL INTERNAL-COMPRESSION INTAKE AT A FREE-STREAM MACH NUMBER OF 2.5. Appendix A - METHODS OF ESTIMATING THE EQUIVALENT CROSS SECTIONAL AND PERFORATED AREA DISTRIBUTION. D. Brown. UTIA TN 18, May, 1957. 35 pp. Experimental investigation conducted at zero angle of attack using wall perforation to bleed off the excess mass flow. Stable running conditions are obtained. A maximum total pressure recovery equal to 81% of the free stream total pressure is obtained at the measuring plane downstream of the throat, with a perforated to throat area ratio of 4.28 and a geometric exit area to throat area ratio of 1.13.

FLOW-TURNING LOSSES ASSOCIATED WITH ZERO-DRAG EXTERNAL-COMPRESSION SUPERSONIC INLETS. R. C. Meyer. US, NACA TN 4096, Oct., 1957. 18 pp. Analysis indicating that, for zero-drag external-compression inlets, the inherent loss in total pressure in turning the flow back to the axial direction after supersonic compression may at times become as high as 20% of the inlet recovery at Mach 4.0. The analysis is based on momentum and continuity considerations and is applicable to most zero-drag inlets. For zero-drag single-cone inlets, the effect of including turning losses decreases the cone angle required for optimum pressure recovery. The momentum-continuity analysis applied to the evaluation of inlet turning losses yields a wind tunnel starting criterion which supplements the usual Kantrowitz condition and is particularly appropriate for the testing of high-drag models.

DROP-SIZE DISTRIBUTION FOR CROSSCURRENT BREAKUP OF LIQUID JETS IN AIRSTREAMS. Appendix A - SAMPLE CALCULATION OF MEAN DROP DIAMETER D_{30}. Appendix B - DIMENSIONAL ANALYSIS. R. D. Ingebo and H. H. Foster. US, NACA TN 4087, Oct., 1957. 36 pp. Study of atomization of liquid jets under conditions similar to those for fuel atomization in ramjet engines and afterburners. In this investigation a high-speed camera, capable of photographing microscopic droplets traveling at high velocities in airstreams, is used in combination with a sampling probe technique. Drop-size-distribution data are obtained by using simple orifice injectors oriented normal to the airflow. The breakup of fuel jets is investigated for ranges of injector, liquid, and airstream variables. Empirical expressions are derived from a dimensional analysis of the data.

THE DEVELOPMENT OF A VARIABLE MACH NUMBER EFFUSER. J. B. McGarry. Gt. Brit., NGTE Rep. R.210, Aug., 1957. 26 pp. Experimental investigation of a simple, two-dimensional variable Mach Number effuser, or nozzle, designed for supersonic flows up to M = 3. The performance of the nozzle is assessed from the magnitude of the percentage variation in its exit Mach Number distribution. Studies of the effect on the performance of alterations to the position of the nozzle block pivots and other geometrical features are included.

Stability & Control

AN INVESTIGATION ON THE INFLUENCE OF AMPLITUDE, SIDEWASH EFFECTS AND FREQUENCY ON THE AERODYNAMIC DERIVATIVES OF A MODEL OSCILLATING CONTINUOUSLY IN YAW. Appendix A - DETERMINATION OF YAWING DERIVATIVES FROM OSCILLATION TESTS. J. Yff. Netherlands, NLL TN F.204, July 16, 1957. 44 pp. Study of the relationship between the amplitude of the yawing oscillation and the sidewash due to wing body interference. Oscillation tests are performed for various values of the sidewash coefficient, rate of change in sidewash to angle of side slip $\frac{\partial \sigma}{\partial \beta}$. Variations in the parameters are obtained by changing the vertical position of the wing. Results indicate that there is no dependence of damping in yaw on the amplitude or on the sidewash coefficient. The directional stability, however, does show a small systematic influence of the amplitude, while the dependence on the sidewash coefficient is also quantitatively in accordance with the analytically predicted proportionality between the directional stability and the tail efficiency factor $(1 + \frac{\partial \sigma}{\partial \beta})$. Both damping in yaw and directional stability did not show a systematic dependence on the frequency of oscillation.

Wings & Airfoils

A METHOD FOR THE ASYMPTOTIC EXPANSION OF THE INTEGRAL EQUATION OF A LIFTING SURFACE AT NEAR-SONIC SPEEDS. W. Eckhaus. Netherlands, NLL TN F.200, Apr. 15, 1957. 15 pp. Presentation of a method which can be applied to a large class of integral equations, of which the kernel contains a small parameter. Approximations of an arbitrary high order can be deduced directly from the complete integral equation in a simple manner. Moreover the terms omitted are presented in a closed form, making it possible to investigate the applicability of the asymptotically approximated equation.

THE SUPERSONIC MOTION OF AN AEROFOIL THROUGH A TEMPERATURE FRONT. J. W. Craggs. J. Fluid Mech., Nov., 1957, pp. 176-184. Development of a solution for the sound waves generated when an infinite wedge passes at supersonic velocity through the plane interface between different media. The results are then applied to the special case when two media consist of the same perfect gas at different temperatures. It is observed that the flow can be deduced for any symmetrical airfoil of infinite span by superposition, and the case of a double wedge is considered in detail.

SUR LA DETERMINATION LOCALE D'UNE AILE OPTIMUM EN REGIME SUPERSONIQUE. P. Germain. La Recherche Aéronautique, Sept. - Oct., 1957, pp. 3-12. 10 refs. In French. Study of the problem of an optimum airfoil producing minimum drag in the supersonic region. The developed method is applied to study the case of a wing with an elliptical plan form, and the results are analogous to those obtained by Jones.

COMPARATIVE CALCULATIONS OF DIVERGENCE SPEED FOR WINGS OF NOT TOO LARGE ASPECT RATIO. A. I. van de Vooren and O. Schatz. Netherlands, NLL TN F.197, Jan. 9, 1957. 15 pp. Evaluation of divergence speed calculated separately from the strip theory, lifting line theory, and lifting surface theory. Due to the forward shift of the center of pressure occurring for wings of low effective aspect ratio, the value found by lifting surface theory can be appreciably lower than that obtained from lifting line theory. Also the torsional deformation below the divergence speed will be underestimated by lifting line theory.

ZUM ÜBERGANG VON DER ERWEITERTEN ZUR EINFACHEN TRAGLINIENTHEORIE BEI SCHIEBENDEN UND GEPFEILTEN FLÜGELN. Erich Truckenbrodt. ZFW, Sept., 1957, pp. 259-264. 12 refs. In German. Application of an appropriate conversion to the extended lifting line theory (three-quarter-point method) to calculate yawing and swept wings of large aspect ratio by means of the Prandtl simple lifting line theory.

THE FORCES ON A THIN AEROFOIL IN SLIGHTLY PARABOLIC SHEAR FLOW. E. E. Jones. ZAMM, Sept. -Oct., 1957, pp. 362-370. Determination of the aerodynamic characteristics of a thin cambered airfoil when it is set at incidence in a shear flow of compressible inviscid fluid. First order effects are deduced assuming that the deviation from uniform flow is small, the velocity profile being parabolic.

A NOTE ON THE CAUSE OF THE NOSE STALL OF THIN WINGS. D. G. Hurley and N. Ruglen. Australia, ARL AN 162, May, 1957. 26 pp. Experimental investigation on a 6% thick wing designed to locate the position of the initial separation responsible for nose stall. The results indicate that stall is delayed by porous suction located downstream of the small laminar bubble, thus supporting Wallis' contestation. These results are more conclusive at the highest Reynolds Number covered (4.85×10^6) than at the lower Reynolds Numbers.

AEROELASTICITY

AEROELASTIC EFFECTS ON DYNAMIC BEHAVIOR OR AIRCRAFT. Lee Arnold. France, ONERA, J. I. S. A., Paris, May 27-29, 1957, Comptes Rendus, Pt. 2, pp. 69-81. 26 refs. Presentation of techniques now available for studying the influence of aeroelasticity on the dynamics of flight, and discussion of some of the problem areas with the emphasis on prediction. Included are methods for the determination of structural influence coefficients; the aerodynamic considerations in subsonic, transonic, supersonic, and hypersonic flight regimes; the aeroelastic response to random disturbances; coupling between aeroelastic elements and the automatic control system, and methods of dynamic measurements to improve the theoretical considerations.

SUPERSONIC PANEL FLUTTER. Appendix I - SOLUTION OF THE MEMBRANE PROBLEM BY PERTURBATION. Appendix II - EQUATIONS USED TO DERIVE ENGINEERING DATA FROM BASIC CURVES. Y. L. Luke and A. St. John. USAF WADC TR 57-252 [AD 118238], July, 1957. 76 pp. 15 refs. Presentation of panel flutter equation for the finite aspect ratio plate-membrane, and derivation of the air forces in a form convenient for computation. General numerical results are obtained, and the thickness required for aluminum panel stability is presented as a function of altitude and aspect ratio for the Mach Number range 1.3 to 1.5.

GRAPHICAL AND TABULATED DATA ON THE FREQUENCY AND MODAL CHARACTERISTICS OF SWEPT CANTILEVERS. Appendix A, B - THEORETICAL CALCULATIONS. Appendix C - PROFILE CAMBER. A. H. Hall, H. A. Tulloch, H. F. L. Pinkney and A. C. Sarazin. Canada, NAE LR 193, June, 1957. 95 pp. Presentation of comprehensive data useful in the application of semi-rigid analysis to preliminary design studies of missile and aircraft dynamics. Charts of frequency coefficients as a function of angle of sweep, aspect ratio, and rigidity ratio, interpolation tables covering the corresponding modes and running amplitude ratios (nodal coordinates), together with illustrative experimental results are also presented. The profile camber is briefly discussed.

A NEW METHOD OF OBTAINING LOWER LIMITS FOR THE SOLUTIONS OF "EIGENVALUE" PROBLEMS FOR BEAMS AND PLATES. D. Williams. Gt. Brit., RAE Rep. Struc. 225, Aug., 1957. -14 pp. Illustration of the method by its application to simple eigenvalue problems of elastic instability and natural vibration frequencies. It depends on defining the deformation of an elastic system by its displacement at a discrete number of stations, and on expressing curvature in finite-difference form.

UNCOUPLED TORSIONAL VIBRATIONS OF A THIN, TWISTED, ROTATING BEAM. Appendix I - LINEARIZATION OF EQUATION FOR STATIC TORSIONAL DEFLECTION. Appendix II - COMPARISON WITH OTHER THEORETICAL RESULTS. W. G. Brady and W. P. Targoff. USAF WADC TR 56-501 [AD 130786], June, 1957. 24 pp. Development of a method for computing natural uncoupled torsional modes and frequencies taking into account nonlinear effects of static torsional deflection on the torsional stiffness of the beam. Comparison is made of analytical results with experimental data, showing excellent agreement.

THE BENDING VIBRATIONS OF A TWISTED ROTATING BEAM. W. P. Targoff. USAF WADC TR 56-27 [AD 97176], Aug., 1956. 25 pp. 12 refs. Development of a method for computing the natural modes and frequencies. Some numerical results are given and compared with experimental data. A high degree of accuracy is shown. Includes discussion of the conceptual philosophy of the method.

FREE AND FORCED VIBRATIONS OF STRAIGHT ELASTIC BARS ACCORDING TO THE "METHOD OF INTERNAL CONSTRAINTS." E. Volterra and E. C. Zachmanoglou. Ing.-Arch., No. 6, 1957, pp. 424-436. OOR-sponsored analysis for several cases of vibrations in straight bars taking into account the effects of shear and rotary inertia. Lateral and longitudinal eigenvibrations are solved for cases of (a) a simply supported bar, (b) a cantilever bar, (c) a built-in bar, (d) free-free bar, and (e) a bar built-in at one end and simply supported at the other. The equations of motion for lateral forced vibrations are derived along with those of torsional vibrations.

INVESTIGATION OF DEFLECTORS AS GUST ALLEVIATORS ON A 0.09-SCALE MODEL OF THE BELL X-5 AIRPLANE WITH VARIOUS WING SWEEP ANGLES FROM 20° TO 60° AT MACH NUMBERS FROM 0.40 TO 0.90. D. R. Croom and J. K. Huffman. US, NACA TN 4175, Nov., 1957. 28 pp. Test results showing that the deflectors are effective as gust alleviators (the reduction of the lift-curve slope measured through 0° angle of attack) at all wing sweep angles; however, the magnitude of lift curve-slope reduction varies with Mach Number and wing sweep angle. The configuration with the 50° swept wings has the maximum reduction in lift-slope curve and the minimum variation with Mach Number. The deflectors produce an increase in drag at all Mach Numbers and wing sweep angles, and consequently would be effective as aerodynamic brakes.

AN ANALYTICAL INVESTIGATION OF THE GUST-ALLEVIATING PROPERTIES OF A SIMPLE PITCH DAMPER. Appendix A, B - THE CHARACTERISTIC EQUATION. Appendix C - RESPONSE TO UNIT STEP GUST INPUT. Appendix D - RESPONSE TO CONTINUOUS GUSTS. N. L. Crabill. US, NACA TN 4173, Dec., 1957. 47 pp. 17 refs. Study of the response to atmospheric gusts of a lightly damped aircraft model flying at a Mach Number 0.7 at sea level with elevator fixed and with varying amounts of viscous restraint of a mass-overbalanced elevator. For a sharp-edged gust the viscously restrained mass-overbalanced elevator has negligible effect on the motion of the aircraft center of gravity until the first peak in the normal acceleration response of the model has been reached. Then the effective damping ratio of the subsequent motion can be more than trebled by a suitable choice of viscous restraint with some reduction in frequency of oscillation. In continuous gusts, calculations indicate that for the model considered there is a 20% reduction in root-mean-square normal acceleration at the center of gravity over a broad range of elevator viscous restraint.

ON THE MINIMIZATION OF AIRPLANE RESPONSES TO RANDOM GUSTS. Appendix A - TRANSFORMATIONS TO HARMONIC REPONSES OF THE SUPERSONIC INDICIAL FUNCTIONS OF TWO-DIMENSIONAL, RECTANGULAR, AND WIDE TRIANGULAR WINGS. Appendix B - SOLUTION OF INTEGRAL EQUATION FOR $P(\varphi)$. Murray Tobak. US, NACA TN 3290, Oct., 1957. 71 pp. 38 refs. Theoretical study of the motions experienced by aircraft in response to sharp-edge, harmonic, and random gusts. For the sharp-edge and harmonic gusts, exact responses in normal acceleration and pitching velocity are presented for the rectangular wing flying at Mach Number 1.2. These are compared with approximate solutions based on commonly used assumptions, and the validity of each of the assumptions is assessed. The problem of alleviating the airplane's response to random gusts is presented in a form amenable to treatment by the Wiener optimum filter theory.

FATIGUE INVESTIGATION OF FULL-SCALE TRANSPORT-AIRPLANE WINGS; VARIABLE-AMPLITUDE TESTS WITH A GUST-LOADS SPECTRUM. R. E. Whaley. US, NACA TN 4132, Nov., 1957. 43 pp. Presentation of results for simulated flight-history tests on C-46 wing, conducted by the forced vibration method with a spectrum of loads derived from gust-frequency statistics. The results are compared with previously published results of constant-amplitude tests. The average crack occurred more than 3.5 times later than the linear-cumulative-damage theory indicated. The first cracks to appear were predicted reasonably well by the theory, but the cracks that propagated to failure initiated about three times later than the theory indicated. Final failure occurred more than 4.5 times later than predicted by the theory. The spread for crack initiation was about five times as high as the corresponding spread for the constant-amplitude tests.

AIRPLANE DESIGN

AIRBORNE NUCLEAR PROPULSION SYSTEM DESIGN CONSIDERATIONS. R. B. Ormsby, Jr. Aero. Eng. Rev., Jan., 1957, pp. 20-23. Study of the size variation in atomic powered aircraft to emphasize the basic underlying reasons why such aircraft are inherently large and what can be done to improve the situation. Some of the conclusions drawn include: (1) for nuclear powered aircraft there is a design gross weight which is the minimum size aircraft that will just fly and carry no useful load, and this size is a function of reactor power density; (2) as aircraft gross weight is increased, the payload to gross weight ratio becomes larger and eventually approaches the 1 to 4 figure associated with current chemical-powered designs; (3) improved materials which will understand high temperatures and massive doses of nuclear radiation

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will permit a reduction in size of nuclear powered aircraft.

Control Systems

A GEARED FLYWHEEL BALANCE ARRANGEMENT FOR THE PREVENTION OF CONTROL SURFACE FLUTTER. W. G. Molyneux. Gt. Brit., RAE Rep. Struc. 224, June, 1957. 16 pp. Description of some geared massbalance systems effective in eliminating inertial couplings between modes of the main surface and the control surface. They are shown to have an advantage over the conventional arrangement for preventing flutter involving main surface torsion and control rotation, particularly where there is a near frequency coincidence between the modes.

Landing Gear

THE EFFECT OF AIRPLANE STRUCTURAL FLEXIBILITY ON LANDING GEAR LOADS. J. P. Benthem. Netherlands, NLL TN S. 478, Oct. 12, 1956. 87 pp. 24 refs. USAF-supported development of a method for solving the nonlinear differential equations of the landing gear and the linear differential equations of the elastic system of the remainder of the aircraft simultaneously. The landing gear strut is assumed rigid for bending moments and has a velocity-square damping device and preloading by air pressure. Spin-up and spring-back loads are taken into account. The parameters varied in the analysis are the vertical velocity of descent, the number of modes of vibration taken into account, and the bending and torsional stiffnesses of the wing. Includes examination of landing gear locations and a simple method to estimate the importance of wing flexibility.

ELECTRONICS

Piezoelectricity

PIEZOELEKTRISCHE GERÄTE ZUR BESTIMMUNG DES PITOTDRUCKS, DES STATISCHEN DRUCKS, DES DYNAMISCHEN DRUCKS UND DES IMPULSES EINER PULSIERENDEN STRÖMUNG. F. Staab. Ing.-Arch., No. 6, 1957, pp. 404-413. 34 refs. In German. Description of the piezoelectric equipment for measuring pitot, static, and dynamic pressures and impulses of a pulsating flow. Outline of difficulties of measuring rapidly fluctuating pressures, such as occur in some jet engines, rockets, and turbines. Construction, modifications, calibration, and some of the applications are described.

INSTRUMENTS

Flow Measuring Devices

EFFECTS OF PROBE TIP GEOMETRY AND SIZE ON MEASUREMENTS IN A LAMINAR BOUNDARY LAYER IN SUPERSONIC FLOW. S. H. Galezowski. UTIA TN 17, Oct., 1957. 21 pp. Study to determine the effects of the diameter of circular probe tips on boundary layer measurements in supersonic flow, and the establishment of the probe tip size which produces the smallest discrepancy between the measured values and those predicted by the well-established theory of Chapman and Rubesin. It is deduced that boundary layer distortion due to the presence of a total pressure probe in the boundary layer is a function of both its tip width to tip height ratio and its tip height to boundary layer thickness ratio.

CARAGRAPHE - INSTRUMENT POUR LA DETERMINATION GRAPHIQUE D'ECOULEMENTS PLANS SUPERSONIQUES PAR LA METHODE DES CARACTERISTIQUES. Gérard Gontier. France, Min. de l'Air NT 67, 1957. 26 pp. 14 refs. SDIT, 2 Av. Porte-d'Issy, Paris 15, Frs. 475. In French. Description of the caragraph as a device used for graphical determination of bi-dimensional supersonic irrotational flows by the method of characteristics. The significance of caragraph elements, its advantages, and applications are also included.

Pressure Measuring Devices

MEASUREMENT OF STATIC PRESSURE ON AIRCRAFT. William Gracey. US, NACA TN 4184, Nov., 1957. 71 pp. 51 refs. Presentation of existing data on the errors involved in the measurement of static pressure by means of static-pressure tubes and fuselage vents at subsonic, transonic, and supersonic speeds. Includes static-pressure errors for isolated tubes and vents and for installations ahead of the fuselage nose, wing tip, and vertical tail fin, and on the fuselage. Various calibrating methods are discussed.

MATERIALS

THE USEFUL HEAT CAPACITY OF SEVERAL MATERIALS FOR BALLISTIC NOSE-CONE CONSTRUCTION. J. R. Stalder. US, NACA TN 4141, Nov., 1957. 19 pp. Analysis of heat-absorption characteristics of several materials for possible use in construction of ballistic missile heat sinks, taking into account the variation of material properties with temperature; made for conditions corresponding to a typical ballistic-missile trajectory. Copper, Inconel-X, graphite, and beryllium are considered, and it is found that significant weight saving could be achieved by using graphite or beryllium instead of copper. It is further indicated that large errors in computed temperature distributions can arise by conventional approximation of the Fourier heat-conduction equation.

Metals & Alloys

ACHROMATISME EN RAYONNEMENT X; APPLICATION A L'ETUDE DES RAIES DE DIFFRACTION DE LA SOLUTION SOLIDE ALUMINIUM-CUIVRE A 4% AU COURS DU DURCISSEMENT STRUCTURAL. F. Sebilleau. France, ONERA Pub. 87, 1957. 64 pp. 23 refs. In French. Investigation into the optics of achromatic systems. The theory of diffraction x-rays, due to a disturbed and bounded crystal lattice, is also examined. Results are applied to the analysis of diffraction rays of the matrix of an Al-Cu alloy (4% Cu) during the structural hardening.

INVESTIGATION OF THE COMPRESSIVE STRENGTH AND CREEP OF 7075-T6 ALUMINUM-ALLOY PLATES AT ELEVATED TEMPERATURES. W. D. Deveikis. US, NACA TN 4111, Nov., 1957. 28 pp. 10 refs. Results of test at temperatures from room temperature to 600°F (compressive strength) and from 350°F to 500°F (creep) for V-groove edge supported plates. Test data are compared with calculations obtained from procedures for estimating maximum strength from material stress-strain curves and creep-failure stresses from isochronous stress-strain curves. The strength and creep results are also compared to similar results from tests on 2024-T3 aluminum-alloy plates.

MISSILES

PERFORMANCE OF LONG RANGE HYPERVELOCITY VEHICLES. A. J. Eggers, Jr. (ARS Semi-Annual Meeting, San Francisco, June 10-13, 1957.) Jet Propulsion, Nov., 1957, pp. 1,147-1,151. Analysis of the performance of ballistic, skip, and glide vehicles. Powered flight is treated for an idealized propulsion system which is analogous to current rocket motors. Unpowered flight is characterized by a return to earth along a ballistic, skip, or glide trajectory. Several observations are made on the design of a manned glide vehicle and on the reentry and recovery of satellite vehicles.

THE USE OF LIFT FOR RE-ENTRY FROM SATELLITE TRAJECTORIES. Antonio Ferri, Lewis Feldman, and Walter Daskin. (Astronautics Symp., San Diego, Feb., 1957.) Jet Propulsion, Nov., 1957, pp. 1,184-1,191. Analysis of the reentry problem for a lifting vehicle. Results show that the use of lifting vehicles having a moderate amount of heat sink alleviates the heating problem during reentry. The decelerations occurring during reentry can be kept to acceptable values for manned vehicles, and the promise of a damped phugoid trajectory is outlined. It is suggested that the surfaces used to produce the drag required for deceleration can be used to produce lift and drag without additional complication, and that, in order to increase radiation, open-type lifting surface be used.

PHYSICS

SCATTERING OF ELECTROMAGNETIC WAVES BY AN ACOUSTIC DISTURBANCE IN THE ATMOSPHERE. Andreas Tonning. Appl. Sci. Res., Sect. B, No. 6, 1957, pp. 401-421. Analysis of scattering caused by monochromatic sound waves. The variations in density associated with an acoustic wave are shown to influence the propagation of an electromagnetic wave. The variation in electric permittivity of the atmosphere caused by an acoustic wave is expressed by the power density of the wave. Under the assumption that the acoustic waves are spherical, the scattered field at large distances is given in terms of definite integrals which are evaluated by means of the method of "stationary phase." The limiting case of plane acoustic waves is discussed.

POWER PLANTS

Atomic

ZUR FRAGE DER VERWENDBARKEIT THERMONUKLEARER REAKTIONEN IN RAKETEN. I. H. J. Kaeppeler. Raketentech. & Raumfahrtforsch. Oct., 1957, pp. 60-70. 101 refs. In German. Analysis of the energy extraction from the fusion of light kernels including suggestions for rocket propulsion systems and ignition of nuclear reactors. It is shown that this analysis has to be carried out in relation with the development of a stationary fusion reactor. Includes a concise outline of plasma physics and transport phenomena

Jet & Turbine

THRUST AUGMENTATION OF JET ENGINES BY EXHAUST REHEAT. G. G. Levy. Canada, NAE Quart. Bul., July 1-Sept. 30, 1957, pp. 1-12. Analysis of reheat theory, and consideration of applications and advantages of a system where part of the reheat fuel is injected upstream of the turbine, thus cooling the critically hot turbine blades before being burned in the tailpipe. Reheat system components are described including the following: diffuser, flameholder, combustion duct, fuel injectors, ignition, fuel control system, variable area final nozzle, and cooling shroud.

Rocket

PROPELLANT VAPORIZATION AS A CRITERION FOR ROCKET-ENGINE DESIGN; CALCULATIONS USING VARIOUS LOG-PROBABILITY DISTRIBUTIONS OF HEPTANE DROPS. R. J. Priem. US, NACA TN 4098, Oct., 1957. 29 pp. Calculations indicating that the chamber length necessary to vaporize a given high percentage of fuel increases with increasing geometric standard deviation and mass-median drop radius. The results are correlated with an effective length and are compared with experimental results. The experimental results correlate with the calculations for sprays having a geometric standard deviation of 2.5 and mass-median drop radii of 70 to 280 microns, depending on the injector type. A small number of large drops that do not vaporize may be responsible for the loss in engine performance.

THEORETICAL ROCKET PERFORMANCE OF JP-4 FUEL WITH SEVERAL FLUORINE-OXYGEN MIXTURES ASSUMING FROZEN COMPOSITION. Sanford Gordon and K. S. Drellishak. US, NACA RM E57G16a, Nov. 13, 1957. 62 pp. 15 refs. Calculation over a range of pressure ratios and oxidant-fuel ratios of specific impulse, combustion-chamber temperature, nozzle-exit temperature, molecular weight, characteristic velocity, coefficient of thrust, ratio of nozzle-exit area to throat

area, specific heat at constant pressure, isentropic exponent, viscosity, and thermal conductivity. A correlation is given for the effect of chamber pressure on several of the parameters.

PROPELLERS

DEVELOPMENT OF A PROPELLER AERODYNAMIC STRIP ANALYSIS EMPLOYING AN ITERATIVE INDUCED INFLOW TREATMENT FOR SOLUTION ON A HIGH SPEED DIGITAL COMPUTER. J. P. Cooper and S. E. Tate. USAF WADC TR 57-527 [AD 130997], Sept., 1957. 17 pp. Presentation of an analysis using Theodorsen's extension of Goldstein's theory as the basis for a rapidly convergent iteration process in determining the propeller induced inflow. Performance problems for single rotation propellers including normal, chordwise, and side force calculations for the yawed propeller condition may be computed by this method.

STRUCTURAL AND VIBRATIONAL CHARACTERISTICS OF WADC S-2 MODEL PROPELLER BLADES. M. O. Burquest and J. E. Carpenter. USAF WADC TR 56-28 [AD 130785], June, 1957. 84 pp. Experimental investigation on test blades instrumented with wire resistance gages, and rotated at various positive and negative blade angle settings up to speeds of 8,000 r.p.m. The blades are vibrated in the fundamental bending mode, second bending mode, and the first torsion made at various pitch angles and rotational speeds. Experimental data are also obtained for the steady strains produced by centrifugal force as well as for the blade damping for various vibratory test conditions. The blade vibratory characteristics are analytically determined for several combinations of blade angle setting and rotational speed, and good correlation is obtained between these analytical results and the experimental results.

ROTATING WING AIRCRAFT

INVESTIGATIONS OF GROUND RESONANCE IN HELICOPTERS WITH AN ANALOGUE COMPUTER. H. Fuchs. Helicopter Assn. Gt. Brit. J., Oct., 1957, pp. 263-290. Solutions for ground resonance using an analog computer, presented for both the simple Coleman theory and the case of "bouncing." The results indicate that the computer solution, in the simple case, agrees with the analytical solution within about 1%. In the case of bouncing the helicopter becomes more unstable due to reductions in both the damping and stiffness in the undercarriage degree of freedom at the peaks of the oscillation.

SAFETY

ACCELERATIONS IN FIGHTER-AIRPLANE CRASHES. Appendix - DESCRIPTION OF TELEMETERING DATA RECORDING SYSTEM. L. W. Acker, D. O. Black, and J. C. Moser. US, NACA RM E57G11, Nov. 4, 1957. 78 pp. Investigation on full-scale fighter aircraft to determine the magnitude, duration, and direction of accelerations imposed on the aircraft structure and pilot during simulated crash landings. Accelerations are measured on the aircraft structure and on an anthropomorphic dummy installed in the cockpit of an FH-1 aircraft. Crash simulations include three unflared landings, each at a different impact angle, a ground cart wheel, and a ground loop.

SPACE TRAVEL

ENTWICKLUNGSSTAND 1957 DER UNBEMANNTEN FLUGKÖRPER, ÜBERSCHALL-FLUGGERÄTE UND RAUMFAHRZEUGE. Eugen Sänger. Forschungsinst. Phys. Strahlantriebe Mitteil. 12, Oct., 1957. 141 pp. In German. Actual stage of development of unmanned missiles, supersonic aircraft instruments and space vehicles including the military, commercial, technical, scientific, and cultural aspects of supersonic flight and space travel. Different types of supersonic fighters, fighter rockets (air to air missiles), combat rockets, supersonic bombers, unmanned bombers, rocket bombers, unmanned earth satellites, unmanned space vehicles, and research instruments are presented.

THE EFFECT OF THE EARTH'S MAGNETIC FIELD ON THE SPIN OF THE SATELLITE. H. B. Rosenstock. Astronautica Acta, Fasc. 3, 1957, pp. 215-221. The angular velocity ω as a function of time t of a sphere or spherical shell rotating about an axis perpendicular to a uniform magnetic field B is given by $\omega(t) = \omega(0) \exp(-t/\tau)$, where the time constant τ, besides depending on the nature of the material, is inversely proportional to B^2. Application of these results to the proposed satellite moving in the geomagnetic field. τ is found to be of the order of ten days.

KREMNEVYE SOLNECHNYE BATAREI KAK ISTOCHNIKI ELEKTRICHESKOGO PITANIIA ISKUSSTVENNYKH SPUTNIKOV ZEMLI. V.S. Vavilov, V.M. Malovetskaia, G.N. Galkin, and A.P. Landsman. Uspekhi Fiz. Nauk, No. 1a, Sept., 1957, pp. 123-129. 15 refs. In Russian. Discussion covering silicon solar batteries as sources of electric power supply for telemetering and research instruments in artificial earth satellites.

NEKOTORYE VARIATSIONNYE ZADACHI, SVIAZANNYE S ZAPUSKOM ISKUSSTVENNOGO SPUTNIKA ZEMLI. D.E. Okhotsimskii and T.M. Eneev. Uspekhi Fiz. Nauk, No. 1a, Sept., 1957, pp. 5-32. In Russian. Study of the problem of launching of an artificial earth satellite into its orbit. This is assumed to be possible by means of a rocket accelerator with one or more stages. The investigation is directed toward defining a technique (thrust - variation in time) in order to orient the satellite to its orbit with minimum fuel expenditure. An attempt is made to determine the most effective regime of fuel consumption. The solutions are obtained by means of simplifying assumptions and permit to establish the character-

istics of optimal conditions of the launching on the basis of which it is possible to develop the rocket accelerators with minimum initial weight.

OPREDELENIE VREMENI SUSHCHESTVOVANIIA ISKUSSTVENNOGO SPUTNIKA ZEMLI I ISSLEDOVANIE VEKOVYKH VOZMUSHCHENII EGO ORBITY. D. E. Okhotsimskii, T. M. Eneev, and G. P. Taratynova. Uspekhi Fiz. Nauk, No. 1a, Sept., 1957, pp. 33-50. In Russian. Development of a rapid and accurate method for the determination of the lifetime of a satellite (including the circular and elliptical orbits), study of the secular disturbances of its orbit, and presentation of graphs and tables. The presented results permit also the determination of a law for the variation in time of orbit parameters in the case of any given satellite parameters and for a wide range of orbit parameters. The high-speed electronic computer (BESM) of the Academy of Science, SSSR, is used to integrate the equations. Results of the numerical calculation are based on certain assumptions pertaining to the structure of upper atmospheric layers.

O VLIIANII GEOFIZICHESKIKH FAKTOROV NA DVIZHENIE SPUTNIKA. I. M. Iatsunskii. Uspekhi Fiz. Nauk, No. 1a, Sept., 1957, pp. 59-71. In Russian. Study of the effect of geophysical factors on the motion of an artificial earth satellite. Establishment of a problem pertaining to the specification of coefficients included in the mathematical expression of disturbing forces, based on satellite coordinates.

O DVIZHENII ISKUSSTVENNOGO SPUTNIKA V NETSENTRAL'NOM POLE TIAGOTENIIA ZEMLI PRI NALICHII SOPROTIVLENIIA ATMOSFERY. G. P. Taratynova. Uspekhi Fiz. Nauk, No. 1a, Sept., 1957, pp. 51-58. In Russian. Development of a method using a high-speed electronic computer to calculate the orbit of an artificial earth satellite, taking into account the basic disturbing forces acting on the satellite. Includes development of a method of integration and derivation of the equation of motion of a satellite in the eccentric gravity field.

ON THE APPLICATION OF THE METHOD OF VARIATION OF ELLIPTIC ORBIT ELEMENTS IN CASE OF A SATELLITE VEHICLE. J. M. J. Kooy. (7th Internatl. Astronautical Congress, Rome, Sept. 19, 1956.) Astronautica Acta, Fasc. 3, 1957, pp. 179-214. Outline of the determination of six elliptical orbit elements of the instantaneous Keppler motion of an artificial earth satellite and of the application of the method of variation of orbit elements, if the influences of the oblateness of the earth and the atmospheric drag, as well as the solar and lunar disturbing forces are taken into account, for the purpose of using the satellite as a celestial tool for geophysical research. By measuring the variation of elliptic orbit elements with time and comparing these measurements with the results of calculation based on different assumptions as to internal terrestrial mass distributions and atmospheric density, it is possible to obtain an experimental verification.

STRUCTURES

THE CRIPPLING STRENGTH OF COMPRESSION ELEMENTS. George Gerard. J. Aero. Sci., Jan., 1958, pp. 37-52. 26 refs. Review of a new method applicable to both formed and extruded elements and stiffened panels. Includes test data on various aluminum, magnesium, and titanium alloys and steels presented in terms of generalized parameters, based on the overall geometric configuration of the element and on the elastic modulus and compressive yield strength. The method is checked by test data on short-time crippling at elevated temperatures, and extended to the creep crippling problems by suitable definition of the time-dependent yield strength. Efficiencies of various materials are reviewed and simple methods for new materials under various environmental conditions are proposed.

Connections

DIRECT STRESS FATIGUE TESTS ON REDUX-BONDED AND RIVETED DOUBLE STRAP JOINTS IN 10 S. W. G. ALUMINIUM ALLOY SHEET. S. Kelsey and J. B. Spooner. Gt. Brit., ARC CP 353, 1957. BIS, New York, $1.17. Results of the experimental investigation indicate that bonded joints tend to fail by shear of the bond at the higher stress ranges and by tension of the sheet at the lower stress ranges. Riveted joints fail by tension across the first row of rivets in all cases, though tests on three-row riveted joints show considerable improvement in endurance over those with two rows of rivets.

TESTS ON ECCENTRICALLY LOADED RIVETED JOINTS. A. J. Francis and G. L. Belcher. Australia ARL Rep. SM. 249, Apr., 1957. 28 pp. Experimental investigation on 15 riveted joints in which 24ST aluminum is connected by a group of 24 17ST rivets. The load is statically applied with initial eccentricities varying from ten inches to zero. The strengths obtained are, on the average, 55% in excess of the strengths calculated by the usual procedure for eccentrically loaded splices, but 3.6% below the strengths predicted by a theory which makes allowance for the development of plasticity in plates and rivets.

Cylinders & Shells

SECOND ORDER EFFECTS IN THE FLEXURE OF ISOTROPIC INCOMPRESSIBLE ELASTIC CYLINDERS. W. S. Blackburn. Cambridge Philos. Soc. Proc., Oct., 1957, pp. 907-921. 10 refs. Application of the general theory developed by Green and Spratt. Complex variable notations are used, and the stresses and displacements are obtained in terms of the classical flexure function, the torsion function, and eight other complex potential func-

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tions which satisfy certain conditions on the boundary. These functions are obtained explicitly for the case of an eccentrically loaded circular cylinder, and the stress and displacements are evaluated

Elasticity & Plasticity

EXPERIMENTELLE DURCHFÜHRUNG EINER NEUEN HYDRODYNAMISCHEN ANALOGIE FÜR DAS TORSIONSPROBLEM. G. Grossmann. Ing.-Arch., No. 6, 1957, pp. 381-388. In German. Experimental verification of a new hydrodynamic analogue for the torsion problem. The equations, obtained for the motion of a viscous fluid between a movable disk and a flat surface, are compared with the St. Venant differential equations for the torsional problem. On the basis of this comparison it is shown that torsional resistance and stress can be derived independently of each other by means of time and temperature measurements and calculated with satisfactory accuracy.

A METHOD FOR THE CONSTRUCTION OF FUNDAMENTAL SOLUTIONS IN ELASTICITY THEORY. B. A. Boley. J. Math. & Phys., Oct., 1957, pp. 261-268. ONR-sponsored derivation of integral equations to determine the displacement components due to a concentrated force acting at an interior point of a body of arbitrary configuration, its surfaces being free of tractions. Solutions are obtained by an infinite series method and a sequence method; in the latter each term is derived from its predecessor by a recurrence formula. A discussion of the construction for other types of fundamental singularities is also presented. Application is made to the problem of a concentrated force on an interior point of a semi-infinite solid.

Plates

DER EBENE SPANNUNGSZUSTAND IN EINER DURCH BELIEBIGE EBENE RANDLASTEN BEANSPRUCHTEN ROTIERENDEN VOLLSCHEIBE MIT DEM STÄRKENPROFIL $H(R) = 1/(AR^2 + B)$. Ernst Adams. ZFW, Nov., 1957, pp. 331-334. In German. Investigation of a rotating circular cylindrical disc with the thickness profile $h(r) = 1/(ar^2 + b)$ whose outer edge is subjected to the load of arbitrary plane edge stresses. The plane stresses inside the disc caused by the axisymmetric basic part of the edge load are calculated by means of power series.

Sandwich Structures

ELASTIC STABILITY OF RECTANGULAR SANDWICH PLATES UNDER BI-AXIAL COMPRESSION. J. Guest and J. Solvey. Australia, ARL Rep. SM.251, May, 1957. 69 pp. Application of the Rayleigh method to calculate the buckling loads in the elastic range for rectangular sandwich panels having isotropic cores and faces, with four clamped edges or two opposite edges clamped and two opposite edges simply supported, all subjected to biaxial compression. Results are tabulated as well as plotted in terms of nondimensional parameters. Interaction curves are also plotted to facilitate practical application.

Testing

THE DETECTION OF FATIGUE CRACKS IN SPECIMENS UNDER DYNAMIC LOADING. J. R. Linge. Aircraft Eng., Nov., 1957, pp. 334-342. Test method in which an electrical circuit in the form of a fine insulated copper wire is cemented to the surface of the specimen under test. When a fatigue crack crosses a wire it breaks it in a static manner, and a relay actuates some form of indicating device such as a warning light or bell. The results suggest the method is suitable to give warning of the impending failure in aircraft components and structures under laboratory or flight conditions up to about 10×10^6 cycles.

Thermal Stress

AN ANALYTICAL INVESTIGATION OF CREEP UNDER COMBINED LOADINGS. P. Narasimhamurthy. Aircraft Eng., Nov., 1957, pp. 346-349. Formulation for the laws of creep with a survey of earlier work on the subject. Experimental verifications are discussed along with the nature and form of the creep modulus. The analytical approach is extended to an anisotropic case and a case where the uniaxial creep strain-rate/stress relationship is exponential.

THERMODYNAMICS

Combustion

EFFECT OF INITIAL MIXTURE-TEMPERATURE ON BURNING VELOCITY OF HYDROGEN-AIR MIXTURES WITH PREHEATING AND SIMULATED PREBURNING. Sheldon Heimel. US, NACA TN 4156, Oct., 1957. 23 pp. 15 refs. Investigation using schlieren photographs of open flames; indicating that water produced in preburning chemically promotes the hydrogen-air reaction. This is indicated in three ways: (a) in near-stoichiometric mixtures of hydrogen and air, combustion is made easier by either preburning or preheating; (b) at equivalence ratios of 1.00 and 1.95, mole-for-mole substitution of nitrogen for water vapor in preburning experiments causes no change in burning velocity, even though nitrogen substitution raises the flame temperature; (c) at equal initial temperatures and equal molar ratios of oxygen, the maximum burning velocities of hydrogen-air-nitrogen mixtures are 20% to 30% lower than maximum burning velocities of preburned mixtures.

LA MESURE DES TEMPS CARACTERISTIQUES DE L'EVOLUTION DE LA COMBUSTION DANS UNE CHAMBRE DE FUSEE A PROPERGOL LIQUIDE. M. Barrère, A. Moutet, and P. Sarrat. La Recherche Aéronautique, Sept.-Oct., 1957, pp. 29-40. In French. Development of a method for measuring the characteristic combustion time in a liquid-propellant rocket engine based on the analogy of a cham-

ber equipped with an electric system. Methods for determining the transfer function are reviewed and the experimental technique is described, indicating the way in which characteristic time is deduced from pressure measurements.

Heat Transfer

A METHOD OF COMPUTING THE TRANSIENT TEMPERATURE OF THICK WALLS FROM ARBITRARY VARIATION OF ADIABATIC-WALL TEMPERATURE AND HEAT-TRANSFER COEFFICIENT. Appendix A - REVIEW OF SUPERPOSITION AND TIME SERIES. Appendix B - SUMMARY OF ANALYTICAL TEMPERATURE FORMULAS FOR THICK WALLS. Appendix C - ANALYTICAL TEMPERATURE DISTRIBUTION. P. R. Hill. US, NACA TN 4105, Oct., 1957. 54 pp. Development of a simple method for the calculation of the temperature history of the surfaces of a thick wall or of any plane within the wall. The procedure is to select from a table a set of coefficients which depend on the physical properties of the wall. These coefficients and other data are substituted into explicit algebraic formulas to determine the temperature of the heated wall surface. If the heat-transfer coefficients are known, no guess or iteration procedure is required. The results of the example problems presented indicate that the accuracy can be as good as is desired. For equal time-step sizes, the method is more accurate than more laborious numerical methods.

VTOL & STOL

INVESTIGATION OF THE EFFECTS OF PROPELLER DIAMETER ON THE ABILITY OF A FLAPPED WING, WITH AND WITHOUT BOUNDARY-LAYER CONTROL, TO DEFLECT A PROPELLER SLIPSTREAM DOWNWARD FOR VERTICAL TAKE-OFF. K. P. Spreemann. US, NACA TN 4181, Dec., 1957. 47 pp. Test results indicating that without boundary layer control an increase in the ratio of flap chord to propeller diameter increases the turning angle but decreases the ratio of resultant force to thrust, either in or out of the region of ground effects. It appears that the ratios of flap chord to propeller diameter used in the investigation (0.25 to 0.375) were too low to provide the turning angles normally required for vertical take-off without boundary-layer control. The results also indicate that the increment of turning angle and the increment of the ratio of resultant force to thrust due to boundary-layer control are, in general, independent of the ratio of flap chord to propeller diameter.

TRANSITION-FLIGHT INVESTIGATION OF A FOUR-ENGINE-TRANSPORT VERTICAL-TAKE-OFF AIRPLANE MODEL UTILIZING A LARGE FLAP AND EXTENSIBLE VANES FOR REDIRECTING THE PROPELLER SLIPSTREAM. L. P. Tosti. US, NACA TN 4131, Dec., 1957. 35 pp. Investigation of the stability and control of a four-engine VTO transport aircraft during the transition from hovering to normal forward flight conducted with a remotely controlled free-flight model. The model has a 65%-chord flap which is deflected 85° in hovering flight, eight extensible vanes arranged above the wing in a cascade relation, and four propellers located along the wing with the thrust axes essentially parallel to the fuselage axis. It is found that the model could be flown through the transition range satisfactorily except for some difficulty with a yawing divergence at low speeds.

THE ANNULAR AEROFOIL WITH CENTRAL BODY AND PROPELLER. Svetopolk Pivko. Aircraft Eng., Nov., 1957, pp. 353-357. Presentation of an approximate method for the estimation of the velocity and pressure distribution over the surface of an annular airfoil. A method of combining several standard elementary types of flow is used to represent the parallel flow past an annular airfoil. These include the influence of section thickness, section camber, and angle of attack. The effects of an isolated body of revolution and the flow field of an isolated propeller are then combined in turn with the wing properties to form the complete theory.

WATER-BORNE AIRCRAFT

ROUGH-WATER IMPACT-LOAD INVESTIGATION OF A CHINE-IMMERSED V-BOTTOM MODEL HAVING A DEAD-RISE ANGLE OF 10°. Appendix A - THREE METHODS FOR COMPUTING MAXIMUM IMPACT LIFT COEFFICIENT $C_{L,max}$ FOR MODEL LANDINGS IN ROUGH WATER. M. F. Markey and T. D. Carpini. US, NACA TN 4123, Oct., 1957. 32 pp. Investigation in the Langley impact basin with a model 20-in. wide and 5 ft. long, having a dead-rise angle of 10° and a beam-loading coefficient of 5.78. The impact occurs on waves ranging from 11 ft. to 60 ft. in length and from about 1 ft. to 2 ft. in height (length-height ratios from 8.3 to 43.7). The initial flight conditions are held essentially constant. The trim angle is held fixed at 12° with respect to the horizontal, the flight-path angle is about 6°, and the resultant velocity approximately 65 ft./sec. Time histories of the planing runs are obtained, and few typical time histories are presented to show the wave shape, the position of the model on the wave, and the variation of some impact parameters throughout the impact.

WIND TUNNELS & RESEARCH FACILITIES

A METHOD FOR IMPROVING THE PERFORMANCE OF SHOCK TUBES. A. Russo and A. Hertzberg. Jet Propulsion, Nov., 1957, pp. 1,191-1,193. OSR-supported description of modifications of the basic shock tube to extend the use of hydrogen to the generation of strong shock waves in air. These modifications cover the double-diaphragm shock tube with monatomic buffer gases and a shock tube with an area change at the diaphragm station. Results indicate that the use of a shock tube with an area discontinuity and the proper monatomic buffer

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gas should permit the generation of strong shock waves, using cold hydrogen as a driver gas, with over-all pressure ratios comparable to those required for existing combustion drivers. In addition, by using a buffer gas with the proper atomic weight, it is possible to control the downstream diaphragm pressure ratio in order to minimize the mass of the downstream diaphragm.

REFLEXION VON STOSSWELLEN IN WINDKANÄLEN. B. H. Goethert. ZFW, Nov., 1957, pp. 313-327. In German. Results of theoretical and experimental investigations of the testing possibilities of various types of transonic test sections indicate (for three-dimensional model configurations) that: the wave system produced by cone-cylinder models cannot be effectively absorbed by either conventional perforated or slotted test-section walls. In the case of perforated test sections, it is relatively easy to eliminate reflections of the initial conical shock and the subsequent compression-wave system by suitable selection of the wall geometry. However, the concentrated expansion-wave system originated at the shoulder of the model would be strongly reflected by such a wall. Tests on a cone-cylinder model with 2% blockage in a suitably selected perforated test section of the differential-resistance type as well as in suitably selected combination perforated-slotted test sections with the slots covered with plates of the differential-resistance type verify the theoretical results and show that the wave reflection interferences could be eliminated.

ON THE LIFTING AEROFOIL IN A WIND TUNNEL WITH POROUS WALLS. L. C. Woods. Royal Soc. (London) Proc. Ser. A, Nov. 5, 1957, pp. 341-354. 12 refs. Calculation of the wind tunnel corrections for lift and moment of an airfoil, situated in subsonic two-dimensional flow, midway between walls containing porous sections. The porous wall is assumed to be of such construction that the component of velocity normal to the wall is proportional to the pressure drop across it. Infinite porosity and zero porosity correspond to free streamline and solid wall boundaries respectively, which are thus included in the theory as special cases.

CONFIGURATION DETAILS AND INITIAL PERFORMANCE OF A HYPERSONIC WIND TUNNEL FOR THE RANGE OF MACH NUMBER 8 TO 14. R. E. Thomas, J. D. Lee, and G. L. von Eschen. Ohio U. Res. Found. FTR 2, Oct., 1957. 14 pp. Description of pressurized air heater, nozzle and test chamber, diffuser and vacuum systems which are used in a study to obtain continuous flows of air at Mach Numbers up to 14. The initial results show that the system is capable of starting and operating continuously within the Mach Number range desired. Control features, pressure ratios, cooler performance, and safety requirements are all satisfactory.

AN EXPERIMENTAL INVESTIGATION OF TEMPERATURE AND PRESSURE RECOVERY, RUNNING TIME AND BLOCKAGE CHARACTERISTICS OF THE UTIA 16 INCH x 16 INCH SUPERSONIC WIND TUNNEL. Appendix A - COMPARISON OF THE SPHERE STAGNATION PRESSURE WITH THE STATIC PRESSURE IMMEDIATELY UPSTREAM OF THE SPHERE. J. B. Murray. UTIA TN 16, Aug., 1957. 34 pp. Test results showing no noticeable effect of cone angle or cone frontal area on pressure recovery or running time. The cone angle was found to affect the cone frontal area at which blockage occurs. The recovery temperature in the sphere reaches equilibrium after about 15 secs. and is somewhat below the theoretical recovery temperature due to heat convection losses via the sphere walls to the surrounding atmosphere.

THE GENERATION OF GUSTS IN A WIND TUNNEL AND MEASUREMENT OF UNSTEADY LIFT ON AN AIRFOIL. Appendix I - DESCRIPTION OF TEST TUNNELS. Appendix II - INSTRUMENTATION DETAILS. L. C. Garby, A. M. Kuethe, and J. D. Schetzer. USAF WADC TR 57-401 [AD 130984], June, 1957. 47 pp. 34 refs. Presentation of two methods for generating a gust in a wind tunnel: (1) a moving bump changing the boundary conditions along the wall, and (2) a venetian blind arrangement shedding vortex streets downstream. Measurements are made on a constrained two-dimensional wing model and the results are analyzed. Comparison is made with theory and the equipment is described in detail.

APPLICATION OF MULTIPLE-SOURCE SCHLIEREN SYSTEMS. Appendix I - CALCULATIONS ON AN AUXILIARY PHOTOGRAPHIC RECORDING SYSTEM FOR AEDC 16-FT TRANSONIC TUNNEL SCHLIEREN INSTALLATION. Appendix II - PRISM-TYPE COLOR MULTIPLE-COLOR SCHLIEREN SYSTEM DISTORTION CALCULATIONS. Appendix III - PRODUCTION METHOD FOR A TRICOLOR TRANSPARENCY CUTOFF PLATE. E. Behun. USAF AEDC TR 57-19 [AD 115408], Nov., 1957. 45 pp. Analytical and experimental results of an investigation of three applications of multiple-source schlieren technique. Consideration is given to (1) large perforated-wall transonic wind tunnels requiring mirror optics, (2) color rendition of flow disturbances of perforated-wall transonic tunnels, and (3) exploitation of the sharp-focusing property of the multiple-source schlieren system for application to wind tunnels having transparent side walls.

EFFECTS OF STING-SUPPORT INTERFERENCE ON THE DRAG OF AN OGIVE-CYLINDER BODY WITH AND WITHOUT A BOATTAIL AT 0.6 TO 1.4 MACH NUMBER. George Lee and J. L. Summers. US, NACA RM A57I09, Dec. 3, 1957. 28 pp. Experimental investigation of various sting-support configurations on two bodies of revolution to determine the interference effects on the foredrag and base drag. The tests were made at a Reynolds Number of 8×10^6, based on model length, and over a Mach Number range of 0.6 to 1.4.

operation of the radar equipment and (2) Transhorizon, or scatter, communication have made SAC's Arctic radar warning fence feasible from cost and operational standpoints.

External Power Monitoring of the Model DTB DME Transponder. Ronald M. Fisher and A. W. Randall. *U.S., CAA TDR 306* (*OTS PB 131102*, $0.50.), May, 1957. 7 pp. Modifications of distance-measuring equipment to (a) assure a positive examination of the radiated power output and characteristics of the emitted signal, to (b) improve the linearity and stability of the monitor power-detector circuitry, and to (c) provide a less critical adjustment of the monitor power-threshold control.

PPI Presentation of Time-Shared Videos Having Synchronized or Unsynchronized Antenna Rotation Rates. William E. Miller and Lawrence B. Ii. *U.S., CAA TDR 290* (*OTS PB 131137*, $0.50.), June, 1957. 4 pp. Outline of two applications for a modified Navy Type SPA-8A radar plan-position indicator, and of factors to be considered when time-sharing.

Improvement of Echo Suppression in DME Transponders. A. W. Randall and Roger L. Williams. *U.S., CAA TDR 309* (*OTS PB 131138*, $0.50.), June, 1957. 6 pp.

Semiconductors

The Elemental Semiconductors-Silicon and Germanium, I. J. Shields. *Elec. Energy*, Oct., 1957, pp. 428–433. Discussion of the effects of impurities and crystalline imperfections on the electrical properties of small conductors. A simple physical picture of their roles in electrical conduction processes is given in terms of the band theory of solids.

Semiconductor Symbols; Logical System for Diodes, Transistors and Other Junction Devices. P. M. Thompson and J. Bateson. *Wireless World*, Nov., 1957, pp. 525–528.

Transistor Characteristics and Circuits. Harry C. Likel. *W. U. Tech. Rev.*, Oct., 1957, pp. 129–138. Study of transistor characteristics and some of the more common elementary circuits in which they are employed.

Quasi-Electric and Quasi-Magnetic Fields in Nonuniform Semiconductors. Herbert Kroemer. *RCA Rev.*, Sept., 1957, pp. 332–342. Study of electric movement in semiconductors in which the crystal potential is not perfectly periodic but where, instead, the shape of atomic potential changes gradually from cell to cell if one proceeds through the crystal.

High Frequency Diffused Meltback Transistors. A. B. Phillips and A. M. Intrator. *Electronic Des.*, Sept. 15, 1957, pp. 44–47 ff. Description of five types of silicon transistors, and of the diffused-meltback process by which they are produced.

Wave Propagation

The Large-Signal Behavior of Crossed-Field Traveling-Wave Devices. J. Feinstein and G. S. Kino. *IRE Proc.*, Oct., 1957, pp. 1,364–1,373. Calculation of the limits of validity of the conventional small-signal theory, and employment of an analog computer to follow the interaction to power saturation.

Waveguide Characteristics; Exact Formulae and Curves for the Attenuation and Phase Propagation Coefficients. A. E. Karbowiak. *Electronic & Radio Engr.*, Oct., 1957, pp. 379–387. 12 refs.

Circular Electric Wave Transmission Through Serpentine Bends. H. G. Unger. *Bell System Tech. J.*, Sept., 1957, pp. 1,279–1,291. Application by an iterative process of the general solution of coupled lines with varying coupling coefficient to a serpentine bend, and evaluation of the solution for the elastic curve resulting from a periodically supported line.

Circular Electric Wave Transmission in a Dielectric-Coated Waveguide. H. G. Unger. *Bell System Tech. J.*, Sept., 1957, pp. 1,253–1,278. Solution of the characteristic equation of the cylindrical waveguide with a dielectric layer for the normal modes, in order to find approximate formulas for the phase constants; computation of the increase in attenuation of the normal modes as caused by the dielectric losses in the layer; evaluation of the coupled-wave theory for small differences in propagation constants between the coupled waves; establishment of formulas and curves for designing circular electric waveguides with a dielectric coat; and calculation of the power level in the TE_{om} waves resulting from partial conversion of the power of an incident TE_{01} wave into higher TE_{om} waves at transitions from plain waveguide to dielectric-coated guide.

Normal Mode Bends for Circular Electric Waves. H. G. Unger. *Bell System Tech. J.*, Sept., 1957, pp. 1,292–1,307. Analysis considering a linear taper and taking into account the residual mode conversion in the bend as bend loss. Total bend loss is evaluated for bend configurations which might be useful in circular electric wave transmission.

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Electric

Enameled Magnet Wire. Harry L. Saums and W. W. Pendleton. *Elec. Mfg.*, Oct., 1957, pp. 129–148. 16 refs. Evaluation of properties, and applications as classified by insulation type and by thermal stability.

Developments for AC Power Systems. F. W. Lowry and E. W. Huget. *Can. Aero. J.*, Oct., 1957, pp. 284–286. Discussion of some factors in electrical system design, and how they are best met by a.c. power systems.

AC Lab Checks Out Whole Aircraft Electric System. *Av. Age*, Oct., 1957, pp. 60–63 ff. General description of Canadair Ltd.'s electrical a.c. test facility.

Hydraulic & Pneumatic

Air Ducting System Redesign Saved 113 Lb on C-130. T. Gardner Hill. *Av. Age*, Oct., 1957, pp. 50–53 ff. Case study of Lockheed's two redesigns to achieve a lightweight bleed air-ducting system for the Hercules turboprop.

Design Factors of the Talos Hydraulic System. E. A. Sherrill. *Missile Des. & Devel.*, Oct., 1957, pp. 10–13 ff. Discussion covering hydraulic power, hydraulic control, control frequencies, filter requirements, reliability, contamination control, and design for lifetime reliability.

Flight Operating Problems

Unites States Army Experience in Operations from Unprepared Fields. John F. Denhart. (*NATO AGARD 9th Flight Test Panel, Brussels, Aug. 27–31, 1956.*) *NATO AGARD Rep. 80*, Aug., 1956. 28 pp. Discussion of flight operations, and description and evolution of a Brodie take-off and landing device, in addition to various special landing gears.

L'Accroissement de la Précision à l'Atterrissage par l'Emploi d'Indicateur d'Incidence. P. Lecomte. (*NATO AGARD 8th Flight Test Panel, Rome, Feb. 20–25, 1956.*) *NATO AGARD Rep. 30*, Feb., 1956. 18 pp. In French. Application of an angle-of-attack indicator to the problem of landing approach. The advantages are shown as a decrease in approach speeds and an increase in accuracy of touchdown.

Notes on the Ground-Run of Jet-Propelled Aircraft During Landing and Take-Off. Guiscardo S. Alias. (*NATO AGARD 9th Flight Test Panel, Brussels, Aug. 27–31, 1956.*) *NATO AGARD Rep. 82*, Aug., 1956. 35 pp. 15 refs. Derivation of equations for ground-run distances on an inclined runway which take into account the use of rockets during take-off and reverse thrust and braking parachutes during landing. Graphical methods are also presented.

Flying the Jet Stream. P. R. J. Reynolds and C. L. Chandler. *CAI-IAS Joint Meeting, Montreal, Oct. 21, 22, 1957, Preprint 757.* 21 pp. Members, $0.50; nonmembers, $0.85. Discussion of the origin and make-up of the jet stream, flight planning, and interception and evasion techniques.

Jet Weather. P. D. McTaggart-Cowan. *CAI-IAS Joint Meeting, Montreal, Oct. 21, 22, 1957, Preprint 758.* 9 pp. Members, $0.35; nonmembers, $0.75. Discussion of meteorological problems in dispatch control, very long range flights, commercial jet aircraft operations, and use of the jet stream.

Jet Stream and Jet Aircraft Operations. Elmar R. Reiter. *Navigation*, Summer, 1957, pp. 267–278. Navy-supported study of the effect of vertical and horizontal wind shears upon jet aircraft operations. A technique for minimal flight planning is developed which utilizes trigonometric formulas and allows in-flight corrections if wind forecasts do not provide verification.

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High Energy Fuels Boron-Based Chemicals. *Morris Cohon & Co.*, N.Y., 1957. 22 pp. Discussion of boron fuels as a commercial investment.

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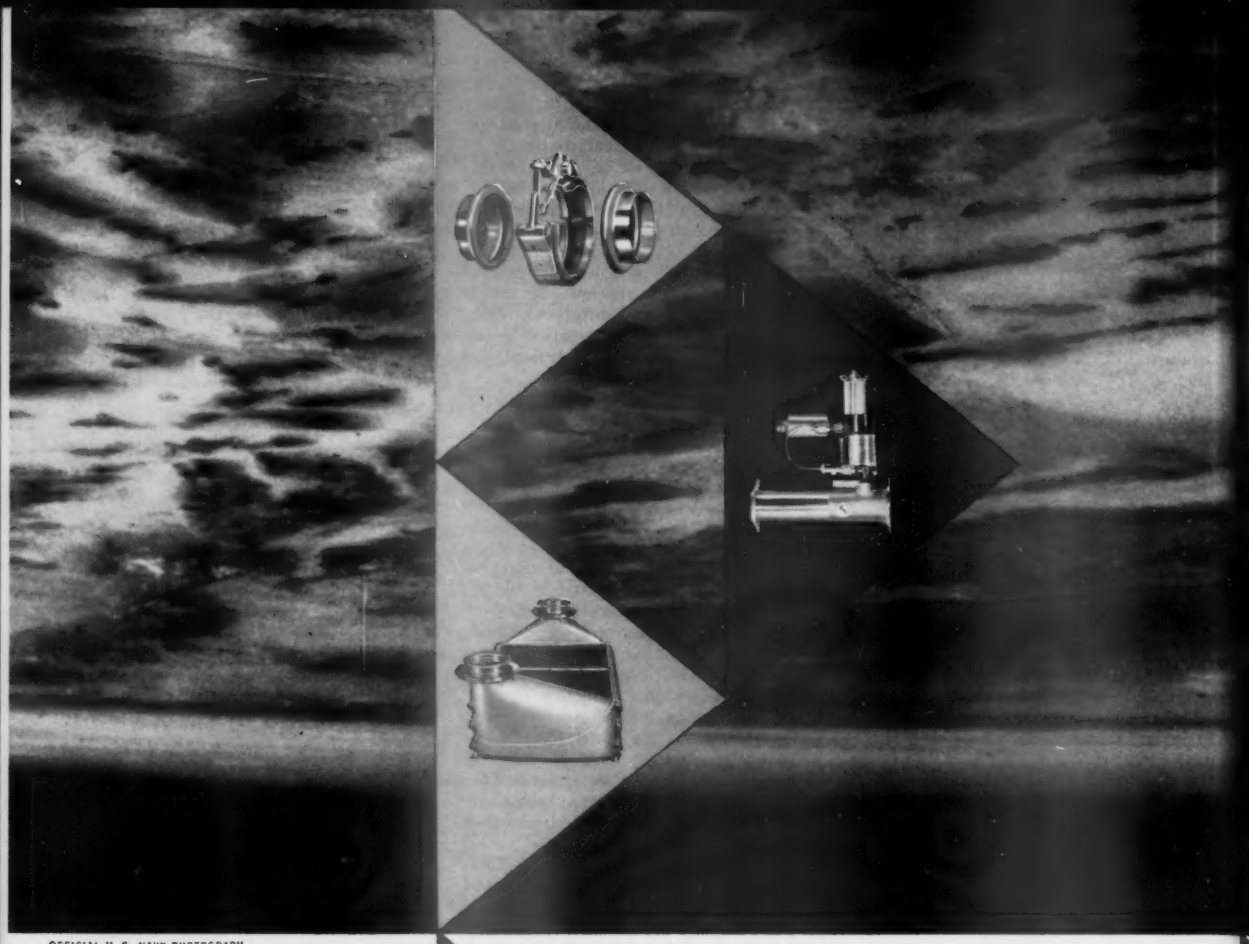

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Some Aspects of the Catalytic Decomposition of Hydrogen Peroxide by Silver. VI—Solutions Saturated with Silver. D. Sutton. *Gt. Brit., RAE TN R.P.D. 153*, May, 1957. 9 pp. Experimental investigation in which the enhanced rate of decomposition, which follows when a solution of hydrogen peroxide is saturated with silver, is shown to be due to the large increase in catalytic surface brought about by the continuous precipitation of particles of silver in the decomposing solution.

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Ice Formation & Prevention

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Impingement of Cloud Droplets on 36.5-Percent-Thick Joukowski Airfoil at Zero Angle of Attack and Discussion of Use of Cloud Measuring Instrument in Dye-Tracer Technique. Appendix A, B—**Review of Dye-Tracer Technique.** Appendix C—**Evaluation of Masking Effect.** R. J. Brun and Dorothea E. Vogt. *U.S., NACA TN 4035*, Sept., 1957. 52 pp. 12 refs.

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A Simple Method for Obtaining Directly an Analog Signal Proportional to the Ratio of Two Transducer Outputs. P. K. Stein. (*SESA Annual Meeting, Columbus, Nov., 1956.*) *SASA Proc.*, Vol. 15, No. 1, 1957, pp. 139–146. (Edited by C. V. Mahlmann and W. M. Murray, Cambridge, Mass., 1957. 200 pp. $6.00.)

Theory and Estimation of Distortion in Optical Oscillograms. W. Hartel. (*Frequenz*, No. 10, 11; 1950, pp. 271–278, 289–294.) *Gt. Brit., RAE Lib. Transl. 682*, July, 1957. 24 pp.

Experiments on Pitot-Tubes in Shear Flow. F. A. MacMillan. *Gt. Brit., ARC R&M 3028* (Feb., 1956), 1957. 12 pp. BIS, New York, $0.72. Measurements, in a pipe of circular section with turbulent flow using pitot-tubes of diameter D, to determine to what degree the shear and presence of the wall may cause the pressure in the tube to differ from the true total pressure on the axis of the tube.

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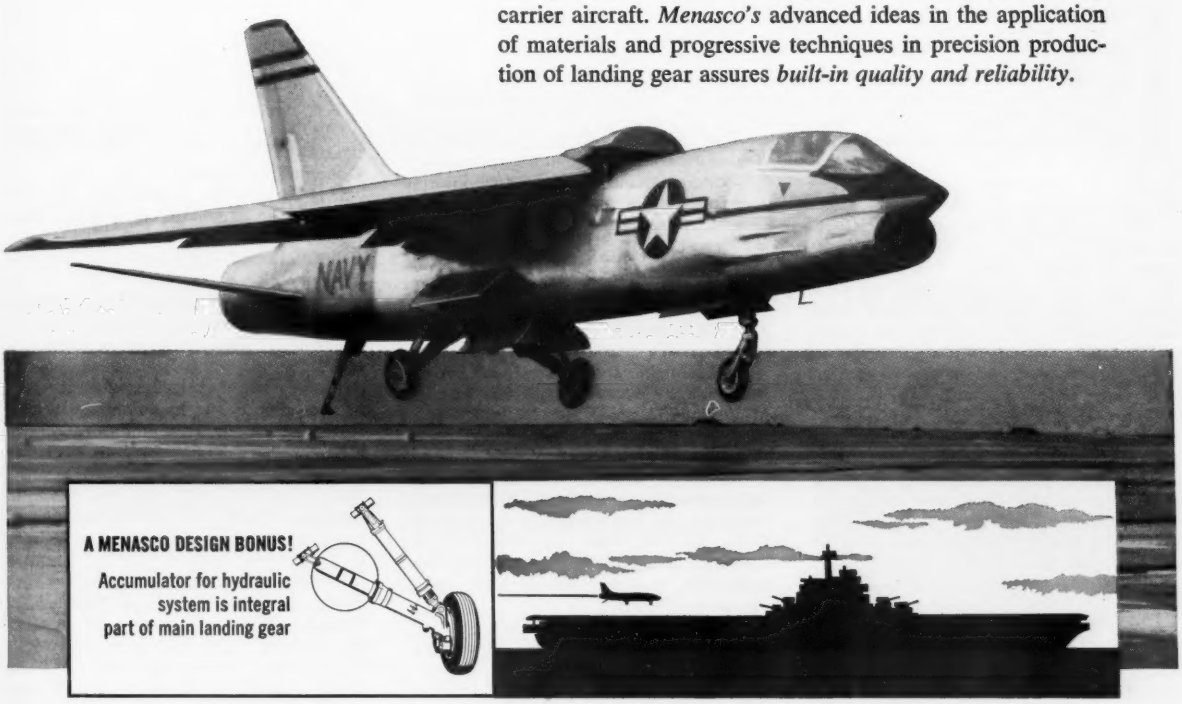

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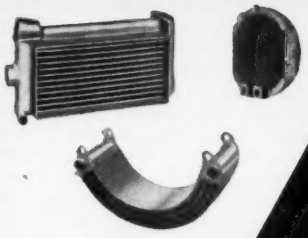

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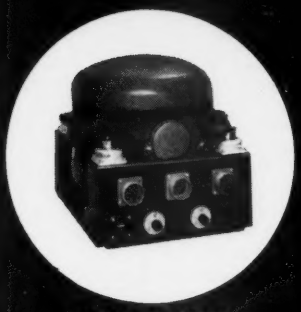

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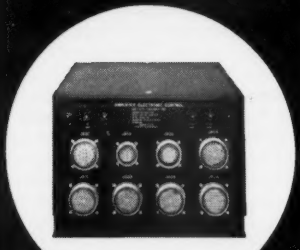
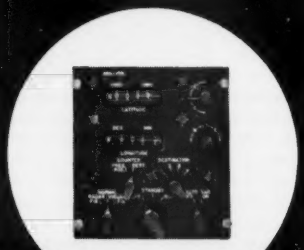


COMPUTER-AMPLIFIER
ANALOG OR DIGITAL



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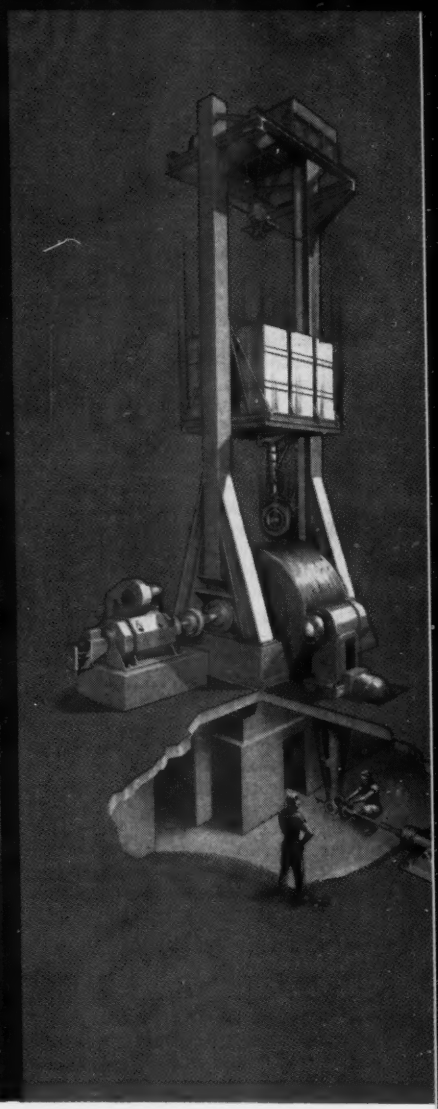

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Diffuzia Vikhrevogo Sloia i Teploobmen. S. A. Regirer. *AN SSSR Dokl.*, June 1, 1957, pp. 737–740. In Russian. Study of the problem of a vortical layer and of heat exchange in a semispace $y \gg 0$ filled with a liquid whose viscosity, thermal conductivity, and heat capacity depend on the temperature. Particular emphasis is placed on the attenuation velocity ratio of initial disturbances—thermal and kinetic.

Obobshchennaia Formulirovka Neravenstva Gibbsa. L. S. Palatnik and A. I. Landau. *AN SSSR Dokl.*, June 1, 1957, pp. 837–840. In Russian. Presentation of a generalized formulation of Gibbs inequality.

Vliianie Podogreva Goriuchei Smesi i Davleniia Okruzhaiushchei Sredy na Predely Stabilizatsii. S. A. Gol'denberg and L. N. Khitrin. *AN SSSR Otd. Tekh. Nauk Izv.*, Feb., 1957, pp. 136–139. 12 refs. In Russian. Study of the influence of fuel-mixture heating and of the pressure of the surrounding medium on the stability limits.

Combustion

A Study on the Explosibility of Ammonia-Air Mixtures. E. Banik. (*Explosivstoffe* No. 5, 1957, pp. 29–32.) *Gt. Brit., MOS TIL/T4799*, Aug., 1957. 7 pp. Translation.

Convection Vive Superficielle. Kemal Onat. *Istanbul Tek. U., Bul*, 1957, pp. 39–49. In French. Results of experiments on convection to emphasize the influence of the surface, taking into account Dumortier's results.

Apparent Emission Intensities from a Turbulent Flame Composed of Wrinkled Laminar Flames. F. Williams and A. E. Fuhs. *Jet Propulsion*, Oct., 1957, pp. 1,099–1,102. Discussion to clarify some of the consequences of the wrinkled laminar flame model.

Estimating Heats of Combustion of Aircraft Fuels. *Tech. News Bul.*, Oct. 1957, pp. 151, 152. Development of a method based on an empirical equation relating heat of combustion to the proportions of various hydrocarbon types present.

A Type of Flame-Excited Oscillation in a Tube. J. J. Bailey. (*ASME Appl. Mech. Div., Summer Conf., Berkeley, June 13–15, 1957, Paper 57-APM-26.*) *J. Appl. Mech.*, Sept., 1957, pp. 333–339. Detailed description of one of two types of instability observed in the burning of propane-air mixtures in an effectively open-ended tube containing a screen flameholder. A driving mechanism is proposed and examined in the light of Rayleigh's criterion, and a linear, one-dimensional theory is presented which takes into account both the driving and damping effects in the system.

Heat Transfer

Test of a Heat Transfer Correlation for Boiling Liquid Metals. W. G. Camack and H. K. Forster. *Jet Propulsion*, Oct., 1957, pp. 1,104–1,106. 13 refs. USAF-supported research.

New Finite-Difference Technique for Solution of the Heat-Conduction Equation, Especially Near Surfaces with Convective Heat Transfer. H. G. Elrod, Jr. (*ASME Annual Meeting, New York, Nov., 25–30, 1956, Paper 56-A-112.*) *Trans. ASME*, Oct., 1957, pp. 1,519–1,526.

The Thermal Instability of a Rotating Fluid Sphere Heated Within. II. S. Chandrasekhar. *Philos. Mag., 8th Ser.*, Oct., 1957, pp. 1,282–1,284. USAF-supported analysis showing that the characteristic value problem specifying the state of marginal stability of a rotating incompressible fluid sphere heated within can be reformulated in terms of a variational principle.

The Principles of Turbulent Heat Transfer. H. Reichardt. (*Arch. für gesamte Wärmetech.*, No. 6/7, 1951, pp. 129–142.) *U.S., NACA TM 1408*, Sept., 1957. 45 pp. 20 refs. Analytical discussion presenting the problem of turbulent heat transfer which is not initially bound by hypothetical assumptions and in which the already known and the still uninvestigated can be clearly distinguished from each other.

VTOL & STOL

Les Installations d'Essais Mises en Oeuvre Pour l'Atar Volant. G. Eggers and J. Jardinier. (*NATO AGARD Flight Test Panel, Brussels, Aug. 27–31, 1956.*) *NATO AGARD Rep. 59*, Aug., 1956. In French. Discussion of preliminary testing leading up to flights of the complete machine, the Atar Volant VTOL test bed.

Un Intéressant V.T.O.L.—Le Biréacteur Bell X. 14. *Air Rev.*, Sept., 1957, pp. 481, 483. In French. Design, description, and operating characteristics of the Armstrong Siddeley Viper twin jet Bell X. 14.

VTOL Transport Aircraft: A Brief Discussion of Canadian Requirements and Project Study Results for Tilting-Wing Configurations with Two Propellers and Four Propellers. P. J. Pocock and A. J. Bowker. *Canada, NAE LR 204*, Sept., 1957. 46 pp. Study of configurations for two proposed missions with a payload of 2,000 and 5,000 lbs., a range of 500 miles, and a hovering time of 10 min. at 6,000 ft. It is shown that the VTOL can be expected to have direct operating costs amounting to 1.68 and 1.98 times the corresponding figure for conventional aircraft.

NACA Research on VTOL and STOL Aeroplanes. M. O. McKinney. *6th Anglo-American Aero. Conf., Folkestone, Sept. 9–12, 1957, Paper.* 27 pp. 35 refs. Research covering two general fields: stability and control, and general aerodynamics (or performance) in hovering and at low speeds. Emphasis is on the problems that are encountered and the solutions, if any, that are worked out.

Flying the H.D. 34. Arcturus. *Flight*, Sept. 20, 1957, pp. 479, 480. Discussion of handling qualities and interior layout of a French STOL photographic-survey aircraft.

Water-Borne Aircraft

Investigation of High Length/Beam Ratio Seaplane Hulls with High Beam Loadings; Hydrodynamic Stability. XIX —The Interaction of the Effects of Forebody Warp, Afterbody Length and Afterbody Angle on Longitudinal Stability Characteristics. J. K. Friswell. (*Gt. Brit., MAEE Rep. F/Res/255*, Sept., 1955.) *Gt. Brit., ARC CP 352.* 45 pp. 18 refs. BIS, New York, $1.17.

Runways at Sea. *Air U. Quart. Rev.*, Winter, 1956–57, pp. 53–65. Appraisal of the advantages and disadvantages of water as a base of operations in modern air warfare.

Wind Tunnels & Research Facilities

Design and Development of the North American Aviation Trisonic Wind Tunnel. W. Daniels, Jr. (*NATO AGARD 9th Wind Tunnel and Model Testing Panel, Brussels, Aug. 27–31, 1956.*) *NATO AGARD Rep. 67*, Aug., 1956. 47 pp. Description of a 7- × 7-ft. blowdown wind tunnel with a Mach Number range from 0.2 to 3.5.

English Electric Proposed Blow-Down Wind Tunnel. F. E. Roe. (*NATO AGARD 9th Wind Tunnel & Model Testing Panel, Brussels, Aug. 27–31, 1956.*) *NATO AGARD Rep. 68*, Aug., 1956. 21 pp. Presentation of basic design data for two tunnels and estimate of the optimum characteristics obtained, showing the economic and technical advantage of utilizing a single power source for both tunnels.

The Face of Progress. Matt Portz. *Pegasus*, Sept., 1957, pp. 1–5. Discussion of wind-tunnel facilities at Lewis Flight Propulsion Laboratory. These facilities include 8- × 6-ft. and 10- × 10-ft. supersonic tunnels. Current and past research projects are reviewed.

Brief Description of the R.A.E. Intermittent Supersonic Wind Tunnel Plant. K. G. Winter. (*Gt. Brit., ARC CP 336*, June, 1956, 1957.) *NATO AGARD Rep. 66*, Aug., 1956. 14 pp.

An Experimental Study of an Aerodynamic Rectifier. Appendix I—**Determination of Unsteady Flow Performance.** Appendix II—**Analysis of Shock Tube Test Results.** Frederick O. Wooten. *USAF WADC TR 57-356 [AD 130779]*, June, 1957. 31 pp. Presentation of design details and principles of operation of an aerodynamic rectifier having no moving parts. For a pressure drop of one psi, it is possible to achieve ten times as much mass flow in one direction as the other.

The Use of an Araldite Coated Iron Casting as a Liner for a Supersonic Wind Tunnel. C. S. Brown and K. G. Winter. (*Gt. Brit., RAE TN Aero. 2443*, May, 1956.) *Gt. Brit., ARC CP 346*, 1957. 8 pp. BIS, New York, $0.27.

The Calibration of a 12 Stage Axial Flow Compressor of 8,000 h. p. A. G. Kurn. *Gt. Brit., RAE TN Aero. 1505*, Apr., 1957. 19 pp. Measurements of mean dynamic pressure, as given by manometer integration, in order to obtain volume flows at two stations of the compressor circuit. Results form a family of curves.

Blow-Down Tunnel Results in 90 Seconds. *Instruments & Automation*, Sept., 1957, pp. 1,704, 1,705. Description of the data reduction system for a supersonic tunnel that measures, scans, computes, and presents results in one continuous operation for each test point as the test progresses.

Data on Temperature Stabilization and Diffuser Performance of the 5 × 5 in. Pilot Blowdown Wind Tunnel. N. B. Tucker. (*NATO AGARD Wind Tunnel & Model Testing Panel, Brussels, Aug. 27–31, 1956.*) *NATO AGARD Rep. 92*, Aug., 1956. 12 pp. Method of achieving temperature control by use of a heat-conducting mass within the high-pressure storage volume. Performance results are given for the variable throat diffuser for Mach Numbers from 2 to 4.

Fabrication de Maquettes à l'Aide des Matières Plastiques. G. Dixmier. (*Gt. Brit., RAE Lil. Transl. 621*, Jan., 1956.) *NATO AGARD Rep. 22*, Feb., 1956. 35 pp. In French. Discussion of the use of reinforced plastics for models which satisfy various aerodynamic test condition.

Techniques for Testing Models of VTOL and STOL Airplanes. John P. Campbell. (*NATO AGARD 9th Wind Tunnel and Model Testing Panel, Brussels, Aug. 27–31, 1956.*) *NATO AGARD Rep. 61*, Aug., 1956. 31 pp. 21 refs. Discussion of free-flying model techniques and some force-testing model techniques.

Precision Machining Techniques as Applied to the Manufacture of Supersonic Wind Tunnel Models. G. W. Rawlings. (*Gt. Brit., RAE TN A.D.W.2*, Feb., 1956). *NATO AGARD Rep. 23*, Feb., 1956. 21 pp. Discussion of the problems encountered in production of scale prototypes, and outline of methods used in solving them. The models discussed include airfoil-research, complete aircraft, and guided-missile types.

Some Comments on High-Life Testing in Wind Tunnels with Particular Reference to Jet-Blowing Models. A. Anscombe and J. Williams. (*Gt. Brit., RAE TN Aero.2460*, June, 1956.) *NATO AGARD Rep. 63*, Aug., 1956. 33 pp.

Inspection Techniques Applied to the Metrology of Aerodynamic Models. H. T. Hill. (*Gt. Brit., RAE TN A.D.W.1*, Jan., 1956). *NATO AGARD Rep. 24*, Feb., 1956. 20 pp.

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Dateline World

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applicable have never been very popular or found widespread application. It will be noted that Gol'denberg's "block" specimen is suitable for only an extremely limited range of hardenabilities. Actually, the standard hardenability specimen is generally used in the U.S. for steels with hardenabilities for which Gol'denberg would recommend the block specimen. It is recognized that the standard specimen is not too sensitive in this range, but it does permit detection of unsatisfactory heats with low hardenability.

The only specific grade mentioned is 30KhGSA, which is said to have a critical cooling rate of 15°C./min. If this is interpreted as an average, it would mean that the standard Cromansil has a hardenability comparable to AISI 4140.

Pavlov Proposes Method to Measure Layer of Steel

◆ Soviet metallurgist T. I. Pavlov has proposed an electrical method for measuring the thickness of a case-hardened layer of steel.

An ordinary four-arm bridge is used. Two arms are induction coils (L_1 and L_2) with U-shaped disconnected iron cores. One of these coils is the pickup for determining the depth of the hardened layer. The other two arms of the bridge serve as semiwindings of the differential choke.

XUM

Aeronautical Reviews — BOOKS

AERONAUTICS, GENERAL

Proceedings of the National Naval Aviation Meeting (Unclassified Portions), San Diego, Calif., August 5–10, 1957. Sponsored by the Institute of the Aeronautical Sciences in cooperation with the U.S. Navy and the San Diego Section of the IAS. New York, IAS, 1957. 123 pp., illus., diagrs. $5.00.

Contents: For Naval Aviation—A Bright Future, Thomas S. Gates, Jr. Some Thoughts on True Sea Basing Aircraft, D. B. MacDiarmid. The Navy and Industry—Partners for Air Progress, J. H. Kindelberger. ONR Objectives and Problems in Aeronautics, A. B. Metsger. The Sea Master: Its Development and Some Consideration from the Accidents, J. L. Decker. The Hydrofoil: Its Development and Application to Water Based Aircraft, William P. Carl and Henry B. Suydam. A New Method for Predicting the Hydrodynamic Characteristics of Waterbased Aircraft, Robert H. Oversmith. Nuclear Power Plants for Air-Borne Vehicles, R. Zirkind. The Systems Approach to the Selection of VTOL Aircraft Design Specifications, F. David Schnebly. Development of a Vertical Take-Off Jet Propelled Aircraft, H. L. Braasch and R. A. Fuhrman. Some Considerations in the Design and Testing of Horizontal-Attitude VTOL Jet Airplanes, George D. Ray. Helicopter Towing Capabilities, D. A. Richardson and G. G. Spratt. Analysis of Air Warfare Problems, Frederick M. Gloeckler. The Human Factor—The Most Neglected Element in Design, J. Sinkankas. The Role of Land Planes in Naval Aviation, E. M. Davis. Operational Problems Posed by Limited Endurance Life of Naval Combat Aircraft, C. Philemon Baum. Carrier Take-Off Considerations (Part I—Aerodynamics; Part II—Structural), E. R. Heald and J. E. Barth. Progress in Naval Use of Air Refueling, A. M. McKenzie. The Role of Flight Safety Engineering in Aircraft Reliability and Effectiveness, C. O. Miller. Manufacturing Research and Development for Terrier Missile, E. D. Heller.

Civil Air Regulations and Flight Standards for Pilots. 18th Ed. Los Angeles, Aero Publishers, Inc., July, 1957. 160 pp., diagrs. $2.25.

Produced by the Associated Aeronautical Staff of Aero Publishers, this profusely illustrated guide to safe flight contains the new "cross-country" examination for private pilots, important civil air regulations, and recommended methods of complying with these regulations. In addition, information is supplied on the following areas of aeronautical knowledge: (1) how to obtain the various pilot certificates and ratings; (2) radiotelephone use; (3) instructions on how to fly; (4) airport traffic control; (5) visual flight rules; (6) questions and answers for private pilot examinations; (7) air defense identification zones; (8) weather services; (9) search and rescue information.

CHEMISTRY

Modern Chemistry for the Engineer and Scientist. Edited by G. Ross Robertson. New York, McGraw-Hill Book Company, Inc., 1957. 442 pp., illus., diagrs., tables. $9.50.

The third volume resulting from the engineering extension lecture courses at the University of California at Los Angeles presents recent advances in many areas of the science of chemistry and its industrial applications. The authors are nationally known academic or industrial chemists.

Contents: Chemical Thermodynamics, Kenneth S. Pitzer. Twenty Years of Progress in Contact Catalysis, Paul H. Emmett. Photochemistry, Its Interest and Its Value, W. Albert Noyes, Jr. Chemical Kinetics and Fast Reactions, Norman Davidson. Isotopic Tracers in Chemistry, Clifford S. Garner. Column Chromatography and Some Applications in Stereochemistry, Laszlo Zechmeister. Organic Reaction Mechanisms, Saul Winstein. Fundamental Aspects of Rubber Elasticity, Herman F. Mark. Carbon-Fluorine Compounds, A New Field of Chemistry, Nelson W. Taylor. Silicones, Eugene G. Rochow. The Petrochemical Industry, Theodore W. Evans. Some Chemical Relations in the Earth, George C. Kennedy. Creep of Metals as a Reaction-Rate Phenomenon, John E. Dorn. Crystal Chemistry and Pyrochemistry of Clay Materials, Joseph A. Pask. New Developments in Food Technology, Donald K. Tressler. The Biochemistry of Insecticides, Robert L. Metcalf. Some Relations between Chemical Constitution and Physiological Action, Gordon A. Alles. Chemical Synthesis in Living Organisms, Theodore A. Geissman. The Configuration of Polypeptide Chains in Proteins, Linus Pauling.

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Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

COMBUSTION

Sixth Symposium (International) on Combustion, at Yale University, New Haven, Conn., August 19–24, 1956. (Published for the Combustion Institute.) New York, Reinhold Publishing Corporation, 1957. 943 pp., illus., diagrs., tables. $28.

In contrast to previous symposiums organized by the Combustion Institute which emphasized such physical and chemical aspects as wave phenomena, turbulence, and reaction kinetics, the Sixth Symposium undertook a broad treatment of combustion and combustion-related topics. Over 200 authors from ten countries contributed papers embracing information on theoretical concepts and principles of engineering applications relating to many aspects of combustion—chemical, kinetic, aerodynamic, and thermodynamic. A total of 125 papers appear in this volume: 37 on the structure and propagation of laminar flames, six on the structure and propagation of turbulent flames, eight on high-speed reactions, eight on flame stabilization in fast streams, four on instability in combustion chambers, five on ignition, eight on combustion of solid fuels, eleven on combustion of explosives and solid propellants, nine on evaporation and combustion of droplets and sprays, nine on experimental and analytical techniques in combustion, and 20 on applications of combustion. Résumés of panel discussions on future problems in combustion research, high-speed reactions, and flame stabilization in fast streams are also presented.

EDUCATION

Graduate Student Enrollment and Support in American Universities and Colleges, 1954. (National Science Foundation, NSF 57-17). Washington, Superintendent of Documents, 1957. 302 pp., diagrs., tables. $1.50.

An estimated 88,500 graduate students of education were enrolled in the nation's colleges and universities during 1954, as compared to 58,000 in the natural sciences, humanities, psychology, and other fields. However, only 4 per cent of the graduate students of education received stipends in the form of assistantships or fellowships in contrast to 60 per cent of those studying the natural sciences and 25 to 30 per cent of those in engineering, psychology, the social sciences, and the humanities; the median yearly stipend ranging from $1,560 in engineering to $920 in education.

These are some of the data contained in the report conducted by the NSF in the spring of 1954. The survey is one in a series of studies of the money and manpower invested in scientific research by Government, industry, and nonprofit institutions. The broad aim of the studies is to provide the public, private agencies, and the Government with knowledge needed for an intelligent appraisal of the nation's research effort and the formulation of sound policies with respect to scientific research and education. The survey enables comparisons to be made for the first time between the patterns of enrollment and support in the broad fields of the physical sciences, biological sciences, social sciences, and the humanities, as well as between the specialized fields of physics, mathematics, meteorology, biochemistry, anthropology, geography, political sciences, or music.

ENGINEERS

Salaries and Earnings of Engineering Teachers, 1956. William H. Miernyk and Morris A. Horowitz. (Prepared for Committee on Development of Engineering Faculties of The American Society for Engineering Education.) Urbana, Ill., The Society, 1957. 19 pp. tables. $0.25.

This report is supplemental to *Professional Income of Engineers—1956* published by the Special Surveys Committee of Engineers Joint Council in January, 1956, and reveals additional information about the salaries and earnings of engineering teachers by faculty rank, number of years in the profession, and geographic location. Its purpose is to provide a more extensive analysis of the structure of these salaries than was possible earlier, and an effort has been made to avoid duplicating the results presented in the EJC report. Instead of presenting the CDEF analysis in terms of medians, all of the results reported here are in terms of the arithmetic mean.

ELECTRICAL ENGINEERING

Standard Handbook for Electrical Engineers. Prepared by a Staff of Specialists; Archer E. Knowlton, Editor-in-Chief; R. M. Shoop, Assistant Editor. 9th Ed. New York, McGraw-Hill Book Company, Inc. 1957. 2,230 pp., diagrs., tables. $19.50.

All branches of electrical engineering practice are touched upon in this standard reference work which last appeared in 1948. The ninth edition recognizes the essential advances achieved in the electrical arts during the last decade and is the creation of a hundred collaborators from industry and the educational world whose aim is to provide within one volume the most frequently required fundamentals, theory, developments, and practices encountered in this complex field.

Some of the areas in which new or extended material has been included are the transistor, nuclear power, new dielectrics for capacitors, new synthetic resins and plastics, electrical measurement for automation, new lighting, recent metals like titanium and zirconium, electric conductor tables recast on basis of new ASTM standards, 12-volt automotive system, power cables, highest transmission voltages, telemetering, new international electrical units and values, and magnetic amplifiers in motor control. The organization of subject matter is such, progressing from units, definitions, and circuit and machine theory to the various areas of their application, that the book can be adapted for purposes of self-instruction, and the nonengineering reader is enabled to locate his desired technical information and then find it discussed in language he should be able to understand.

ELECTRONICS

Engineering Electronics with Industrial Applications and Control. John D. Ryder. New York, McGraw-Hill Book Company, Inc., 1957. 666 pp., illus., diagrs., tables. $9.50.

This book provides a broad, fundamental coverage of the nonradio areas of electronics, particularly those areas of interest in instrumentation, computation, and general industrial usage. It includes the electronic fundamentals and the operating principles important to computers, industrial control, and servomechanisms.

The emphasis throughout is on underlying principles and basic circuits applicable to various electronic devices and equipment. The treatment is quantitative, rather than descriptive or qualitative. Mathematics and circuit analysis are used to give a fundamental understanding of the material.

Recent advances in semiconductors and transistors are included, particularly a rather fundamental development of the transistor equivalent circuit from four-terminal network theory. Coverage of an unusually broad area has been attempted. Two chapters cover the fundamentals of electronic computation, both by analog and digital methods, as well as fundamental circuits applicable to both forms of computation. Not previously treated in such works is the material on frequency response of amplifiers from both the sinusoidal and pulse standpoints. Illustrative exercises and problems for student solution are included in the text.

Although the text is designed for a senior-level college course or for use by practicing engineers in industry, there is sufficient elementary electronics provided in the first three chapters so that those lacking preliminary preparation can still use the book profitably.

Advances in Electronics and Electron Physics, Vol. 9. Edited by L. Marton. New York, Academic Press, Inc., 1957. 347 pp., illus., diagrs., tables. $9.00.

The previous volumes in this series contained groupings of unrelated critical reviews designed to examine a cross section of various aspects of electronics and electron physics. The present volume temporarily reverses this pattern—the main theme throughout is geophysical and originates from the dedication of this year as the International Geophysical Year—and has two aims: first, to help acquaint geophysicists and their allies with some of the modern methods at their disposal; and second, to acquaint workers in electronics with the extremely interesting problems posed by geophysicists.

Contents: Aurora Borealis, C. T. Elvey. Negative Ions, Lewis M. Branscomb. Radio Observation of Meteors, J. G. Davies. Intensity Variations in Cosmic Rays, D. C. Rose. Radio-Wave Propagation: A Review, R. L. Smith-Rose. Electronics in Oceanography, J. B. Hersey. Contributions of Electronics to Seismology and Geomagnetism, Ben S. Melton.

Transistor A. F. Amplifiers. D. D. Jones and R. A. Hilbourne. London, Iliffe & Sons, Ltd.; New York, Philosophical Library, 1957. 152 pp., diagrs., tables. $6.00.

This book deals systematically with the design of transistor audio-frequency amplifiers and gives the circuitry and design details of a versatile range of amplifiers, including those for high fidelity reproduction and public address systems with undistorted outputs up to 20 watts. The transistor mainly dealt with is the p-n-p germanium type. Discussions include the electrical characteristics of the transistor and how these affect the design of audio-amplifiers, the main problems of designing input stages with high signal-to-noise ratio and output stages of the required output with maximum efficiency and minimum distortion, methods of applying negative feedback and of manually controlling the gain and frequency response, design details of five circuits of proved performance with outputs ranging from 1 to 20 watts, power supplies, complementary symmetry, and some of the many possible applications of transistor audio-amplifiers. The book is based on work carried out at the Research Laboratories of The General Electric Company Ltd. of England.

MATERIALS

Gas Turbine Materials; A Survey of High-Temperature Materials and Their Application to the Gas Turbine. G. Lucas and J. F. Pollock. London, Temple Press Limited, 1957. 163 pp., illus., diagrs., tables. 25*s*.

Intended partially to bridge the gap between textbooks on metallurgy and works concerned with the technology of design and performance of gas turbines, this survey seeks to present the engineer, metallurgist, and student with a unified review of gas-turbine materials. The development and application of high-temperature materials—such as the prominent alloys and special materials of a nonmetallic nature and metal/nonmetal combinations—is thoroughly explored, together with special treatments designed to extend the application of otherwise limited materials. Manufacturing processes in relation to various components also come under examination. The behavior of materials in a stress-temperature environment, with emphasis on the phenomenon of creep, is considered. In addition, the manner in which the thermodynamic design of the gas turbine affects choice of materials is dealt with in two sections devoted to the influence of performance requirements and fuel on operating conditions within the gas-turbine cycle.

Aircraft Materials and Processes. George F. Titterton. 5th Ed. New York, Pitman Publishing Corporation, 1956. 162 pp., illus., diagrs., tables. $7.50.

General in scope and designed to meet the needs of students, engineers, designers, and shop men, this latest edition of a work devoted to aircraft materials and construction places major emphasis on the effects of heat from aerodynamic and jet-engine heating on aircraft materials and includes applications of the newer materials such as titanium, high-temperature materials, plastics, and superstrength steels. The approach is utilitarian and numerous suggestions are presented on the choice of material for particular uses and on the best way of working, heat treating, and finishing materials for specific applications.

A Handbook of Hard Metals. W. Dawihl. New York, Philosophical Library, 1956. 162 pp., illus., diagrs., tables. $10.

This is an abridged translation of the author's *Handbuch der Hartmetalle* which dealt with the scientific principles of sintering and the technique of production of hard metals. By removing or condensing all information which is either well known in the industry (and probably outside it) or has been previously published in English, the translators have succeeded in reducing the book to almost one half its original bulk. Reference is made in detail to the experimental methods and results of many other investigators in order to assist further development.

Contents: (1) Introduction. (2) The Metallography of Hard Metal. (3) The Preparation of the Powder Mixtures for Pressing. (4) The Process of Sintering Hard Metal Alloys. (5) The Properties of Sintered Hard Metals. (6) The Processes Taking Place During the Wear of Hard Metal Alloys. (7) Cast Tungsten Carbide Alloys. (8) Hard-Facing Alloys. (9) Diamond Hard Metal. (10) Tungsten-Free Hard Metals. (11) The Production of the Initial and Accessory Materials. (12) The Production of the Powder Mixtures for Pressing. (13) Shaping. (14) Final Sintering. References. Appendix. Index.

A Concise Guide to Plastics. Herbert R. Simonds. New York, Reinhold Publishing Corporation, 1957. 318 pp., illus., diagrs., tables. $6.95.

Written by a consulting engineer specializing in plastics, the *Concise Guide* includes subject matter calculated to answer most practical questions on the uses, properties, cost, or sources of all plastics. The range of material covers the properties of 30 of the best known commercial plastics and their forms; production, prices, and several hundred detailed applications; 25 different processes used in the final fashioning of the finished product; considerations in selecting a plastic for a specific purpose; a listing and brief description of 43 prominent plastics materials manufacturers; and a directory of plastics trade names together with the materials they represent and the companies which produce such materials.

Chemistry of Natural and Synthetic Rubbers. Harry L. Fisher. New York, Reinhold Publishing Corporation, 1957. 208 pp., illus., diagrs. $6.50.

Contents: (1) Elastomers: History and Chemistry. (2) Vulcanization. (3) Acceleration. (4) Antioxidation and Antiozonation. (5) Natural Rubber. (6) Latex. (7) Properties of Natural and Synthetic Rubbers. (8) Some Raw Materials for Synthetic Rubbers. (9) Synthetic Rubbers. (10) Hard Rubber. (11) Bonding Rubber to Metal. (12) Reclaimed Rubber. (13) Chemical Derivatives.

MATHEMATICS

Applied Probability. Edited by L. A. MacColl. (American Mathematical Society. Proceedings of Symposia in Applied Mathematics, Vol. 7.) New York, McGraw-Hill Book Company, Inc., 1957. 104 pp. $5.00.

The Seventh Symposium in Applied Mathematics, sponsored by the American Mathematical Society and the Office of Ordnance Research and devoted to mathematical probability and its applications, was held at the Polytechnic Institute of Brooklyn on April 14–15, 1955. This volume contains the nine papers (one in abstract form) presented at the symposium, which treated three main topics: theory of diffusion, which covers a wide variety of relations between probability theory and the theory of differential equations; theory of turbulence; and probability in classical and modern physics.

Contents: Brownian Motion Depending on n Parameters: The Particular Case $n = 5$, Paul Levy. A New Look at the First Boundary-Value Problem, J. L. Doob. On Boundaries Defined by Stochastic Matrices (Abstract), William Feller. On the Application of Functional Calculus to the Statistical Theory of Turbulence, Eberhard Hopf. Stochastic Processes of Astronomical Interest,

Guido Münch. The Singularity in the Spectrum of Homogeneous Turbulence, G. K. Batchelor. Probability in Classical Physics, Mark Kac. Infinite Models in Physics, S. M. Ulam. Quantum Theory and the Foundations of Probability, B. O. Koopman. Index.

Numerical Analysis. Kaiser S. Kunz. New York, McGraw-Hill Book Company, Inc., 1957. 381 pp., diagrs., tables. $8.00.

All the background material needed for obtaining numerical solutions to advanced problems in applied mathematics is to be found in this book. After a study of numerical solutions of algebraic equations, methods of interpolation, and numerical integration, the text proceeds to an application of the finite difference techniques to ordinary and partial differential equations, and the numerical solution of integral equations. Considerable time is devoted to finite-difference tables and notations and to numerical differentiation and integration, while peripheral subjects such as the smoothing of experimental data, least-squares approximation, and harmonic analysis are omitted. Throughout, mathematical rigor gives way to the free use of symbolic methods and heuristic arguments. The book is the outgrowth of lecture notes prepared by the author for a graduate course in numerical analysis given at Harvard University's Computation Laboratory during the years 1947 to 1949. While the level of mathematics required is modest, a knowledge of calculus and differential equations is presupposed for thorough understanding o the subject matter.

NOISE

Handbook of Noise Control. Edited by Cyril M. Harris. New York, McGraw-Hill Book Company, Inc., 1957. 1,034 pp., diagrs., tables. $16.50.

The first book published in the United States dealing with the general subject of noise control discusses the nature of noise, its measurement, and different techniques of controlling it in buildings, industry, transportation, and the community. The text consists of 40 papers contributed by individuals from Government, industry, and universities who share a vital interest in the problem. The handbook type of presentation has permitted a unified treatment of the specialized areas, while particular stress has been given to the solution of noise problems by the use of examples taken from existing effective installations.

The respective chapters have been organized in the following general groupings: properties of sound, effects of noise on man, vibration control, instrumentation and noise measurement, techniques of noise control, noise control in buildings, sources of noise and examples of noise control, noise control of machinery and electrical equipment, noise control in transportation including aircraft operations, community noise, and the legal aspects of noise problems.

NUCLEAR ENERGY

Selected Papers from the First Nuclear Engineering and Science Congress held at Cleveland, Ohio, 1955. Vol. 1, Problems in Nuclear Engineering; Vol. 2, Reactor Operational Problems. Edited by D. J. Hughes, Stuart McLain, and Clark Williams. London, New York, Pergamon Press, 1957. Vol. 1, 365 pp., illus., diagrs. tables. $17.50. Vol. 2, 278 pp., illus., diagrs.., tables. $17.50.

These volumes contain the most significant of some 358 technical papers presented at the Cleveland Congress in December, 1955, which was primarily concerned with the problems associated with safety and rapid economical heat removal from reactors and the production of low-cost fuel. The collection contains not only information presented earlier in the year at the International Congress on the Peaceful Uses of Atomic Energy held at Geneva but also the declassified information which became available at that meeting but could not be offered because of the time limitations. Since the Cleveland meeting was organized by the Engineers Joint Council, the papers, many of which are original and wider in scope than those presented at Geneva, concentrate upon the engineering aspects of nuclear energy and describe the work performed in Government laboratories or industrial organizations under contract to the Atomic Energy Commission.

Major Activities in the Atomic Energy Programs, January–June, 1957. U.S. Atomic Energy Commission. Washington, Superintendent of Documents, July, 1957. 257 pp., illus., diagrs., tables. $0.75.

The U.S. Atomic Energy Commission states in this report that the Nation's atomic energy programs have made steady progress in developing a variety of power reactors, in setting Government policies to aid the growth and operation of an atomic energy industry, in promoting the free world's utilization of atomic energy for mankind's benefit, and in developing nuclear weapons for defense.

Contents: (1) *Raw Materials:* Domestic Activities, Foreign Activities, Process Development. (2) *Production of Special Nuclear Materials.* (3) *Military Application*: Weapons Testing, Weapons Facilities. (4) *International Activities:* Agreements for Cooperation, Training and Education, Other International Activities. (5) *Civilian Application:* Licenses Requested and Issued, Radioisotopes, Access to Classified Technical Information, Foreign Activities of U.S. Companies, Regulations, Cooperation with State Regulatory Agencies, Materials and Services, Insurance and Indemnity. (6) *Reactor Development:* Civilian Power Reactor Program, Maritime Propulsion Reactors, Military Reactors Program, General Engineering and Development. (7) *Declassification and Classification:* Guides to Declassification, Reviewing Accumulation of Classified Documents. (8) *Information:* General Information, Technical Information. (9) *Education and Training·* Assisting Educational Institutions, University Training Programs, High School Programs, Other Programs. (10) *Physical Research:* Physics, Computer Research, Controlled Thermonuclear Research, Chemistry, Metallurgy. (11) *Biology and Medicine:* Brookhaven Medical Research Center, Studies of Fall-Out, Radiation Effects, Genetics Research, Protection Against Radiation, Toxicity Studies, Beneficial Applications of Atomic Energy, Cancer Therapy and Research, Radiation Detection Instrumentation, Repatriation of the Rongelapese. (12) *Nuclear Materials Management.* (13) *Inspection.* (14) *Construction and Supply.* (15) *Community Operations.* (16) *New Commission Headquarters.* (17) *Organization and Personnel:* Personnel Activities, Safety and Fire Protection, Manpower, Earnings, Labor-Management.

Appendixes: (1) Organization and Principal Staff of U.S. Atomic Energy Commission. (12) Membership of Committees. (3) Major Research and Development Installations of the U.S. Atomic Energy Commission. (4) Radioactive Isotope Distribution Data, Oak Ridge, Tenn. (5) Commission-Owned Patents. (6) Publications of the U.S. Atomic Energy Commission. (7) Regulations of the U.S. Atomic Energy Commission. (8) Production and Utilization Facility Licenses Applied for and Issued. (9) Special Nuclear Material Licenses Applied for and Issued. (10) Health and Safety Procedures Established for 1957 Series of Nuclear Tests in Nevada. (11) Remarks Prepared by Dr. Willard F. Libby, Commissioner, for Delivery Before the American Physical Society, Washington, April 26. (12) Nuclear Reactors Built, Building, or Planned in the United States as of June 30, 1957. (13) Statements and Additional Details Issued in Designating Fuel for Reactors.

PHYSICS

Electricity and Magnetism. J. Newton. New York, Philosophical Library, 1956. 613 pp., illus., diagrs., tables. $10.

Contents: (1) Introduction to Electrostatics. (2) Introduction to Magnetism. (3) The Electric Current. (4) Electrical Power—Resistance. (5) Direct-Current Measurements. (6) Electrolysis and Voltaic Cells. (7) Electromagnetism. (8) Electrodynamics. (9) Electromagnetic Induction. (10) Alternating Currents—Machines. (11) Capacitance. (12) Further Electrostatic Theory. (13) The Magnetic Properties of Materials. (14) Magnetometry, Terrestrial Magnetism. (15) Thermoelectricity. (16) The Units and Dimensions of Electrical Quantities. (17) An Introduction to the Physics of the Atom. (18) Photo-Cells, Valves, and Cathode-Ray Tubes.

POWER PLANTS

Jet Aircraft Power Systems. Jack V. Casamassa and Ralph D. Bent. 2nd Ed. New York, McGraw-Hill Book Company, Inc., 1957. 329 pp., illus., diagrs. $6.50.

The changes and improvements made in gas-turbine engines during the past decade are reflected in this revised edition which contains more than 70 per cent totally new material and illustrations. The arrangement of the book is designed, first, to provide a general understanding of jet-engine theory and components; second, to show how these are applied to modern gas-turbine engines; and third, to discuss operational experience with such engines, and their application to modern transport aircraft. Mr. Casamassa is a Vice-President of Russell Associates, Inc., while Mr. Bent is with the Northrop Aeronautical Institute.

Contents: (1) History and Development of Gas Turbines. (2) Theory of Jet Propulsion. (3) The Aviation Gas Turbine. (4) Rockets. (5) Athodyds—Ramjets and Pulsejets. (6) Comparative Advantages and Disadvantages of Gas-turbine Engines. (7) Gas-Turbine Fuels. (8) Fuel Systems and Controls. (9) Gas-Turbine Starting and Ignition Systems. (10) Lubricants and Lubricating Systems. (11) Air Inlets and Cooling and Exhaust Systems. (12) Thrust Augmentation. (13) Typical Turbojet Engines. (14) The General Electric J47 Turbojet Engine. (15) The General Electric J73 Turbojet Engine. (16) The Turboprop Engine. (17) Commercial Turboprop Engines. (18) Operation, Maintenance, and Overhaul. (19) Service Experience. (20) Materials for Gas-Turbine Engines. (21) Special Applications of Gas Turbines. (22) Modern Jet Transports.

RESEARCH

Federal Funds for Science; VI. The Federal Research and Development Budget, Fiscal Years 1956, 1957, and 1958. (National Science Foundation, NSF-57-24). Washington, Superintendent of Documents, 1957. 60 pp., diagrs., tables. $0.40.

The latest in a series on the federal Government's research and development budget, this report presents data on expenditures for scientific research and development, including funds for increase of R&D plant and an analysis of the Government's financial obligations in terms of administering agencies, character of work, scientific fields, and organizations performing the work.

The Arnold Engineering Development Center. USAF ARDC. Tullahoma, Tenn., ARO, Inc., 1956. 25 pp., illus., diagrs.

This booklet contains information and illustrations released for publication on the occasion of the First National Press Inspection of the AEDC (November, 1955). The material is a comprehensive description of the Center, its mission and work. It describes in detail the various laboratories of the wind tunnel and engine test center, reports some of its testing achievements, and outlines future operations of the AEDC.

STRUCTURES

Structural Design in Metals. Clifford D. Williams and Ernest C. Harris. 2d Ed. New York, The Ronald Press Company, 1957. 655 pp., illus., diagrs., tables. $8.00.

This extensive revision of the 1949 edition contains new illustrative examples that reflect the latest specifications and design methods and treats of the newer structural materials, such as

(*Continued on page 134*)

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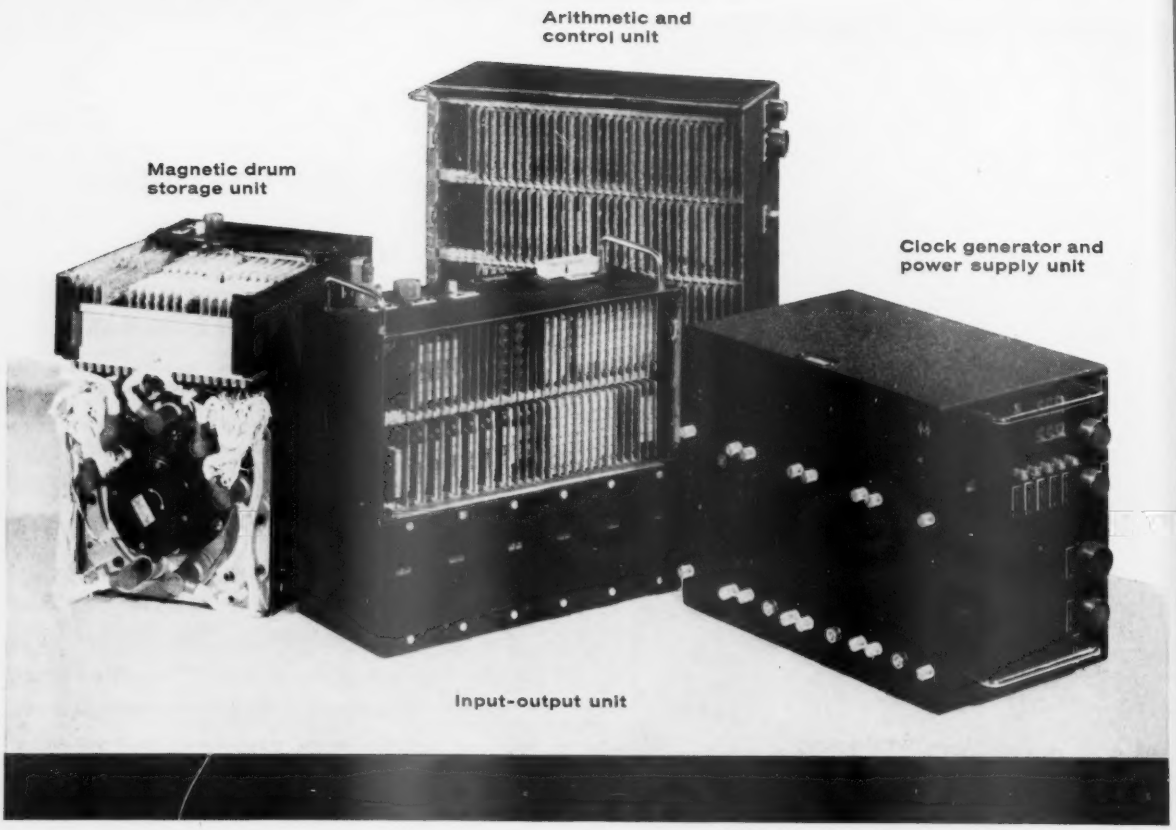

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839. Advertising and Public Relations Manager—B.S. Engineering Management, M.B.A. Industrial Marketing, Ph.D. candidate Advertising. Age 37. Twelve years' intensive experience in industrial marketing techniques: program planning, budgeting, and administration; market and media analysis; agency liaison; and technical advertising, sales promotion, and publicity copy. Government, industry, community, and press relations. Licensed pilot, mechanic, and radioman with marketing background in aviation equipment, air transport, avionics, automation, and nucleonics. Desires broader responsibilities leading to marketing management.

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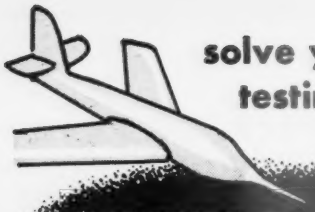

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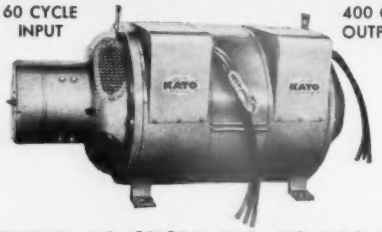

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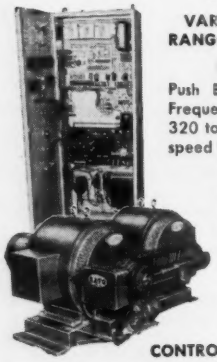

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Books (Continued from page 128)

aluminum and its alloys. The text analyzes the design and applications of rivets, bolts, pins, connections, plate girders, trusses, bearings, light gage structural members, and rigid frames and discusses the selection of sections and the fatigue of structural members. The premise of the authors is that details, if properly designed, should be as applicable to one type of structure as another. Thus, emphasis is placed on the design of details rather than on the complete structure.

Intended as a first course in design at the junior-senior level, the work presupposes a working knowledge of statics and the strength of materials.

Strength of Materials. F. R. Shanley. New York, McGraw-Hill Book Company, Inc., 1957. 783 pp., illus., diagrs., tables. $8.50.

Intended for use in college courses in engineering and science, this basic text does not emphasize any particular field of structures but instead contains material which forms the basis for all types of structural analysis and design. Examples and problems include practical cases from fields of civil, aeronautical, and mechanical engineering. Certain principles of statics are reviewed in the early portion of the book and are extended to include two-dimensional force fields, while considerable attention is given to the direct use of curves (such as the stress-strain diagram) and the solution of problems by the use of tabular computation forms. Among the more advanced subjects discussed are simple engineering methods of predicting inelastic behavior under combined stresses; a general method of predicting the buckling loads for inelastic eccentric columns; and a method of design for repeated loading under stresses of variable amplitude, including stress-concentration effects. All of these subjects can be understood and applied without recourse to advanced mathematical methods (beyond calculus). The author, who is best known for his development of inelastic column theory, is presently Professor of Engineering, University of California, Los Angeles.

TRANSPORTATION

Case Problems in Transportation Management. George P. Baker and Gayton E. Germane. New York, McGraw-Hill Book Company, Inc., 523 pp., illus., diagrs., tables.

This unique work is primarily intended for use in courses concerned with management of transportation companies and secondarily in courses about the economics of transportation or about business management in general. The cases cover a variety of functional activities and are specifically designed to stimulate class discussion. Many recent developments are included in the cases: purchase of jet aircraft, selection of new ships not yet in service, gas-turbine locomotives, railroad operations, railroad and steamship organization problems, and transportation advertising materials. The authors are Professor and Associate Professor of Transportation, respectively, at the Harvard Graduate School of Business Administration and the Graduate School of Business, Leland Stanford Junior University.

✦ ✦ ✦

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